INSTITUTION

OF

MECHANICAL ENGINEERS.

28055

PROCEEDINGS.

1858.

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LIST OF MEMBERS,

WITH YEAR OF ELECTION.

1858.

1848. Adams, William Alexander, Midland Works, Birmingham.
1851. Addison, John, 6 Delahay Street, Westminster, S.W.
1853. Adkins, Francis, Heath Lead Works, near Birmingham.
1858. Albaret, Auguste, Madrid Saragossa and Alicant Railway, Madrid.
1847. Allan, Alexander, Locomotive Superintendent, Scottish Central Railway, Perth.
1856. Allen, Edward Ellis, 37 Brompton Row, London, S.W.
1856. Allen, James, Cambridge Street Works, Manchester.
1856. Anderson, John, Chief Inspector of Machinery, Royal Arsenal, Woolwich, S.E.
1856. Anderson, William, Messrs. Courtney and Stephens, Blackhall Place Iron Works, Dublin.
1858. Appleby, Charles Edward, Mining Engineer, 25 Greenhill, Derby.
1857. Armstrong, Joseph, Great Western Railway, Locomotive Department, Wolverhampton.
1858. Armstrong, William George, Elswick Engine Works, Newcastle-on-Tyne.
1857. Ashbury, James Lloyd, Openshaw Works, near Manchester.
1848. Ashbury, John, Openshaw Works, near Manchester.
1858. Atkinson, Charles, Fitzalan Steel Works, Sheffield.

1848. Bagnall, William, Gold's Hill Iron Works, Westbromwich.
1848. Baker, William, London & North Western Railway, Euston Station, London, N.W.
1847. Barwell, William Harrison, Eagle Foundry, Northampton.
1848. Beattie, Joseph, Locomotive Superintendent, London and South Western Railway, Nine Elms, London, S.
1858. Bell, Isaac Lowthian, Clarence Felling & Wylam Iron Works, Newcastle-on-Tyne.
1857. Bellhouse, Edward Taylor, Eagle Foundry, Hunt Street, Oxford Street, Manchester.
1854. Bennett, Peter Duckworth, Spon Lane Iron Works, Westbromwich.
1847. Beyer, Charles, Messrs. Beyer Peacock and Co., Gorton, near Manchester.
1847. Birley, Henry, Haigh Foundry, near Wigan.
1856. Blackburn, Isaac, Long Eaton, near Derby.
1851. Blackwell, Samuel Holden, Russell's Hall Iron Works, near Dudley.
1858. Bouch, William, Shildon Engine Works, Darlington.

1847. Bovill, George Hinton, Durnsford Lodge, near Wandsworth, Surrey, S.W.
1858. Bower, John Wilkes, Manchester Works, Smethwick, near Birmingham.
1854. Bragge, William, Atlas Steel Works, Sheffield.
1854. Bramwell, Frederick Joseph, 35A Great George Street, Westminster, S.W.
1856. Bray, Edwin, New Dock Iron Works, Leeds.
1848. Broad, Robert, Horseley Iron Works, near Tipton.
1852. Brogden, Henry, Ulverston, Cumberland.
1847. Brown, James, Jun., Messrs. James Watt & Co., Soho Foundry, near Birmingham.
1850. Brown, John, Atlas Steel Works, Sheffield.
1855. Brown, John, Mining Engineer, Barnsley, Yorkshire.
1856. Brown, John, Mining Engineer, Bank Top, Darlington.
1853. Brown, Ralph, Patent Shaft Works, Wednesbury.
1856. Bunning, Theophilus Wood, Ouseburn Engine Works, Newcastle-on-Tyne.
1858. Burlinson, William D., Millfield Engine Works, Sunderland.
1858. Burn, Henry, Midland Railway, Locomotive Department, Derby.
1856. Butler, Ambrose Edmund, Kirkstall Forge, Leeds.

1857. Cabry, Joseph, Midland Great Western Railway, Dublin.
1847. Cabry, Thomas, North Eastern Railway, York.
1847. Cammell, Charles, Cyclops Steel Works, Sheffield.
1856. Carrett, William Elliott, Sun Foundry, Leeds.
1858. Carson, James I., Locomotive Superintendent, West Hartlepool Harbour and Railway, Stockton-on-Tees.
1849. Chamberlain, Humphrey, Clerkenleap, Kempsey, near Worcester.
1852. Chellingworth, Thomas T., Sydenham Works, Westbromwich.
1857. Chrimes, Richard, Messrs. Guest and Chrimes, Brass Works, Rotherham.
1854. Clark, Daniel Kinnear, 11 Adam Street, Adelphi, London, W.C.
1847. Clift, John Edward, Durnford Place, Coventry Road, Birmingham.
1847. Cochrane, Alexander Brodie, Woodside Iron Works, near Dudley.
1858. Cochrane, Charles, Ormsby Iron Works, Middlesborough.
1854. Cochrane, John, Woodside Iron Works, near Dudley.
1847. Coke, Richard George, Ankerbold, near Chesterfield.
1853. Cooper, Samuel Thomas, Hanover Square, Leeds.
1848. Corry, Edward, 8 New Broad Street, London, E.C.
1857. Cortazzi, Francis James, Great Northern Railway, Locomotive Department, Doncaster.
1849. Cowper, Charles, 20 Southampton Buildings, Chancery Lane, London, W.C.
1847. Cowper, Edward Alfred, 35A Great George Street, Westminster, S.W.
1853. Craig, William Grindley, Locomotive Superintendent, Manchester Sheffield and Lincolnshire Railway, Gorton, near Manchester.
1847. Crampton, Thomas Russell, 15 Buckingham Street, Adelphi, London, W.C.
1858. Crawhall, Joseph, St. Ann's Wire and Hemp Rope Works, Newcastle-on-Tyne.

1857. Criswick, Theophilus, Plymouth Iron Works, Merthyr Tydvil.
1858. Cubitt, Charles, Westminster New Bridge Works, South Lambeth, London, S.

1849. Dawes, George, Milton and Elsecar Iron Works, near Barnsley, Yorkshire.
1857. Deane, John Horridge, Barcelona and Granollers Railway, Locomotive Department, Barcelona : (or care of Edward G. Deane, Solicitor, Liverpool.)
1857. De Bergue, Charles, Strangeways Iron Works, Manchester.
1858. Dees, James, Whitehaven.
1858. Dempsey, William, 26 Great George Street, Westminster, S.W.
1854. Dodds, Thomas W., Holmes Engine Works, Rotherham.
1857. Douglas, George, Resident Engineer, Birkenhead Lancashire and Cheshire Junction Railway, Birkenhead.
1857. Dove, George, Woodbank Iron Works, Carlisle.
1856. Dudgeon, John, 151 Fenchurch Street, London, E.C.
1856. Dudgeon, William, 151 Fenchurch Street, London, E.C.
1857. Dunlop, John Macmillan, Marlborough Street, Oxford Street, Manchester.
1854. Dunn, Thomas, Windsor Bridge Iron Works, Manchester.

1858. Easton, Edward, Grove Works, Southwark, London, S.E.
1856. Eastwood, James, Railway Iron Works, Derby.
1853. England, George, Hatcham Iron Works, New Cross, Surrey, S.E.
1857. Evans, John Campbell, Morden Iron Works, East Greenwich, S.E.
1848. Everitt, George Allen, Kingston Metal Works, Adderley Street, Birmingham.

1847. Fairbairn, William, F.R.S., The Polygon, Ardwick, Manchester.
1852. Fairbairn, Thomas, Canal Street Works, Manchester.
1849. Fairbairn, William A., Canal Street Works, Manchester.
1857. Fairlie, Robert Francis, 10 Liverpool Street, New Broad Street, London, E.C.
1856. Fay, Charles, Lancashire and Yorkshire Railway, Carriage Department, Manchester.
1847. Fenton, James, Low Moor Iron Works, near Bradford, Yorkshire.
1854. Fernie, John, Midland Railway, Locomotive Department, Derby.
1847. Fletcher, Edward, Locomotive Superintendent, North Eastern Railway, Gateshead.
1858. Fletcher, Henry Allason, Lowca Engine Works, Whitehaven.
1857. Fletcher, James, Messrs. W. Collier and Co., 2 Greengate, Salford, Manchester.
1849. Forsyth, John C., North Staffordshire Railway, Stoke-upon-Trent.
1849. Forsyth, Thomas, Messrs. Sharp, Stewart and Co., Atlas Works, Manchester.
1847. Fothergill, Benjamin, Queen's Chambers, 5 Market Street, Manchester.
1847. Fowler, John, 2 Queen Square Place, Westminster, S.W.
1857. Fowler, John, Jun., 28 Cornhill, London, E.C.
1847. Fox, Sir Charles, 8 New Street, Spring Gardens, London, S.W.
1853. Fraser, Joseph Boyes, Alma Place, Kenilworth.

1856. Freeman, Joseph, 22 Cannon Street, London, E.C.
1852. Froude, William, Dartington, Totnes, Devonshire.

1847. Garland, William S., Messrs. James Watt & Co., Soho Foundry, near Birmingham.
1848. Gibbons, Benjamin, Hill Hampton House, near Stourport.
1856. Gilkes, Edgar, Tees Engine Works, Middlesborough.
1854. Goode, Benjamin W., St. Paul's Square, Birmingham.
1847. Goodfellow, Benjamin, Hyde Iron Works, Hyde, near Manchester.
1852. Gordon, Robert, Heaton Foundry, Stockport.
1848. Green, Charles, Tube Works, Leek Street, Birmingham.
1858. Greenwood, Thomas, Albion Foundry, Leeds.
1857. Gregory, John, Engineer, Portuguese National Railway South of Tagus, Barriero, near Lisbon : (or care of Hugh Greaves, 5 Victoria Street, Westminster, S.W.)

1857. Hall, William, Bloomfield Iron Works, Tipton.
1858. Harding, John, Beeston Iron Works, Leeds.
1856. Harrison, George, Canada Works, Birkenhead.
1858. Harrison, Thomas Elliot, North Eastern Railway, Newcastle-on-Tyne.
1848. Hartree, William, Messrs. John Penn and Co., Marine Engineers, Greenwich, S.E.
1858. Haswell, John A., North Eastern Railway, Locomotive Department, Gateshead.
1857. Haughton, S. Wilfred, Locomotive Superintendent, Dublin and Wicklow Railway, Dublin.
1856. Hawksley, Thomas, 30 Great George Street, Westminster, S.W.
1848. Hawthorn, Robert, Forth Banks, Newcastle-on-Tyne.
1848. Hawthorn, William, Forth Banks, Newcastle-on-Tyne.
1858. Head, Thomas Howard, Teesdale Iron Works, Stockton-on-Tees.
1853. Headly, James Ind, Eagle Works, Cambridge.
1857. Healey, Edward Charles, 163 Strand, London, W.C.
1858. Headley, John, Resident Engineer, South Hetton Colliery, near Fence Houses.
1847. Henderson, John, Smethwick, near Birmingham.
1850. Henson, Henry H., 38 Parliament Street, Westminster, S.W.
1848. Hewitson, William Watson, Messrs. Kitson and Co., Airedale Foundry, Leeds.
1854. Hodgkin, John Eliot, Borax Works, Old Swan, near Liverpool.
1858. Hodgson, Robert, North Eastern Railway, Newcastle-on-Tyne.
1852. Holcroft, James, Shut End, Brierley Hill, Worcestershire.
1848. Homersham, Samuel Collett, 19 Buckingham Street, Adelphi, London, W.C.
1856. Hopkinson, John, Messrs. Wren and Hopkinson, Altrincham Street, Manchester.
1858. Hopper, George, Houghton-le-Spring Iron Works, near Fence Houses.
1851. Horton, Joshua, Etna Works, Smethwick, near Birmingham.
1858. Horsley, William, Jun., Walker Iron Works, Newcastle-on-Tyne.
1858. Hosking, John, Gateshead Iron Works, Gateshead.
1847. Howell, Joseph, Hawarden Iron Works, Holywell, Flintshire.

1857. Humber, William, Pancras Chambers, Pancras Lane, Bucklersbury, London, E.C.
1856. Hunt, Thomas, London & North Western Railway, Locomotive Department, Crewe.

1850. Ikin, Jonathan Dickson, 2 Cannon Row, Westminster, S.W.
1857. Inshaw, John, Engine Works, Morville Street, Birmingham.

1847. Jackson, Peter Rothwell, Salford Rolling Mills, Manchester.
1853. Jaffrey, George William, Hartlepool Iron Works, Hartlepool.
1856. James, Jabez, 28A Broadwall, Stamford Street, Lambeth, London, S.
1848. Jee, Alfred Stanistreet, 6 John Street, Adelphi, London, W.C.
1855. Jeffcock, Parkin, Mining Engineer, 3 Stuart Terrace, Greenhill, Derby.
1856. Jeffreys, Edward, Locomotive Superintendent, Shrewsbury and Hereford Railway, Shrewsbury.
1857. Jenkins, William, Locomotive Superintendent, Lancashire and Yorkshire Railway, Miles Platting, Manchester.
1854. Jobson, John, Derwent Foundry, Derby.
1847. Jobson, Robert, Wordsley Works, near Stourbridge,
1847. Johnson, James, Great Northern Railway, Locomotive Department, Doncaster.
1848. Johnson, Richard William, The Laurels, Hagley Road, Birmingham.
1849. Johnson, William, 166 Buchanan Street, Glasgow.
1855. Johnson, William Beckett, St. George's Iron Works, Hulme, Manchester.
1847. Jones, Edward, Old Park Iron Works, Wednesbury.
1857. Jones, John Hodgson, 1 Poet's Corner, Westminster, S.W.
1853. Joy, David, 5 Queen Square, Leeds.

1857. Kay, James Clarkson, Phœnix Foundry, Bury, Lancashire.
1857. Kendall, William, Locomotive Superintendent, Blyth and Tyne Railway, Percy Main, near North Shields.
1847. Kennedy, James, 59 Erskine Street, Liverpool.
1857. Kennedy, Lieut.-Col. John Pitt, R.E., Engineer, Bombay Baroda and Central Indian Railway ; 10 Liverpool Street, New Broad Street, London, E.C.
1848. Kinmond, William L., Hamilton Steam Engine and Forge Works, Hamilton, Canada West.
1848. Kirkham, John, 109 Euston Road, London, N.W.
1847. Kirtley, Matthew, Locomotive Superintendent, Midland Railway, Derby.
1848. Kitson, James, Airedale Foundry, Leeds.

1858. Laurent, François, Inspecting Engineer, Rome and Civita Vecchia Railway ; 19 Eldon Square, Newcastle-on-Tyne.
1857. Laybourn, John, Isca Foundry, Newport, Monmouthshire.
1856. Laybourn, Richard, Locomotive Superintendent, Monmouthshire Railway and Canal Company, Newport, Monmouthshire.

1857. Lees, John, Park Bridge Iron Works, Ashton-under-Lyne.
1857. Lees, Sylvester, Locomotive Superintendent, East Lancashire Railway, Bury, Lancashire.
1858. Leslie, Andrew, Iron Ship Building Yard, Hebburn Quay, Gateshead.
1856. Levick, Frederick, Cwm-Celyn Blaina and Coalbrook Vale Iron Works, near Newport, Monmouthshire.
1856. Linn, Alexander Grainger, 121 Upper Parliament Street, Liverpool.
1857. Little, Charles, Midland Railway, Locomotive Department, Derby.
1854. Lloyd, George Braithwaite, Messrs. Lloyds, High Street, Birmingham.
1847. Lloyd, Sampson, Old Park Iron Works, Wednesbury.
1852. Lloyd, Samuel, Jun., Old Park Iron Works, Wednesbury.
1856. Longridge, Robert Bewick, 46 Richmond Grove, Longsight, Manchester.
1854. Lynde, James Gascoigne, Town Hall, Manchester.

1856. Mackay, John, Drogheda Iron Works, Drogheda.
1857. March, George, Union Foundry, Leeds.
1856. Markham, Charles, Midland Railway, Derby.
1848. Marshall, Edwin, Britannia Carriage Works, Birmingham.
1847. Marshall, William Prime, 81 Newhall Street, Birmingham.
1853. Marten, Henry, Parkfield Iron Works, near Wolverhampton.
1857. Martindale, Capt. Ben Hay, R.E., Superintendent of Railway and Civil Works, Sydney, New South Wales.
1854. Martineau, Francis Edgar, Globe Works, Cliveland Street, Birmingham.
1857. Masselin, Armand, Spon Lane Glass Works, near Westbromwich.
1853. Mathews, William, Corben's Hall Iron Works, near Dudley.
1848. Matthew, John, Messrs. John Penn and Co., Marine Engineers, Greenwich, S.E.
1847. Matthews, William Anthony, Sheaf Works, Sheffield.
1857. May, Walter, Suffolk Works, Berkeley Street, Birmingham.
1847. McClean, John Robinson, 17 Great George Street, Westminster, S.W.
1847. McConnell, James Edward, Locomotive Superintendent, London and North Western Railway, Wolverton.
1858. Meik, Thomas, Engineer to the River Wear Commissioners, Sunderland.
1857. Menelaus, William, Dowlais Iron Works, Merthyr Tydvil.
1857. Metford, William Ellis, Flook House, Taunton.
1847. Middleton, William, Vulcan Iron Foundry, Summer Lane, Birmingham.
1853. Miller, George Mackay, Great Southern and Western Railway, Dublin.
1847. Miller, Joseph, F.R.S., Mill Ellers, Dalston, near Carlisle.
1856. Mitchell, Charles, Iron Ship Building Yard, Low Walker, near Newcastle-on-Tyne.
1858. Mitchell, James, Resident Engineer, Dock Works, Silloth, near Carlisle.
1849. Morrison, Robert, Ouseburn Engine Works, Newcastle-on-Tyne.
1858. Mountain, Charles George, Suffolk Works, Berkeley Street, Birmingham.
1857. Mowbray, Frederick William, Queen's Gate, Bradford, Yorkshire.

1857. Muntz, George Frederick, French Walls, near Birmingham.
1856. Muntz, George Henri Marc, 3 Lansdowne Terrace, Handsworth, near Birmingham.
1858. Murray, Thomas H., Engine Works, Chester-le-Street, near Fence Houses.

1848. Napier, John, Vulcan Foundry, Glasgow.
1856. Napier, Robert, Vulcan Foundry, Glasgow.
1858. Naylor, William, Great Indian Peninsula Railway, 3 New Broad Street, London, E.C.
1856. Newall, James, East Lancashire Railway, Carriage Department, Bury, Lancashire.
1858. Nichol, Peter Dale, East Indian Railway, Locomotive Department, Howrah, Calcutta: (or care of Anthony Nichol, Quay Side, Newcastle-on-Tyne.)
1851. Nixon, Charles, 26 Great George Street, Westminster, S.W.
1850. Norris, Richard Stuart, London and North Western Railway, Engineer's Office, Liverpool.

1847. Owen, William, Messrs. Sandford and Owen, Phœnix Works, Rotherham.

1858. Parkinson, John, Victoria Brass and Copper Works, Bury, Lancashire.
1853. Payne, Edward J., 1 Bennett's Hill, Birmingham.
1847. Peacock, Richard, Messrs. Beyer Peacock and Co., Gorton, near Manchester.
1848. Pearson, John, Liver Iron Works, Boundary Street, Liverpool.
1856. Perring, John Shae, Resident Engineer, East Lancashire Railway, Bury, Lancashire.
1856. Piggott, George, Birmingham Heath Boiler Works, Birmingham.
1854. Pilkington, Richard, Jun., St. Helen's Foundry, St. Helen's.
1852. Plant, Reuben, Pensnett Collieries, Brierley Hill, Worcestershire.
1856. Pollard, John, Midland Junction Foundry, Leeds.
1852. Porter, John Henderson, Iron Roofing Works, Gas Street, Birmingham.
1856. Preston, Francis, Ancoats Bridge Works, Ardwick, Manchester.
1848. Preston, Robert B., 10 Abercromby Square, Liverpool.
1855. Prideaux, Thomas Symes, 32 Charing Cross, London, S.W.

1847. Ramsbottom, John, Locomotive Superintendent, London and North Western Railway, Crewe.
1856. Reeves, Charles, Toledo Works, Charlotte Street, Birmingham.
1857. Rennie, George, 21 Whitehall Place, Westminster, S.W.
1856. Richards, Josiah, Ebbw Vale Iron Works, near Newport, Monmouthshire.
1847. Richards, Thomas, Gas Works, Whitehaven.
1858. Richardson, Thomas, Hartlepool Iron Works, Hartlepool.
1848. Robertson, Henry, Shrewsbury and Chester Railway, Shrewsbury.
1847. Robinson, Henry, 8 Chandos Street, Cavendish Square, London, W.
1858. Robson, Jonathan, Blackwall Engine and Iron Ship Building Works, Gateshead.

1852. Rofe, Henry, Engineer, Birmingham Water Works, Paradise Street, Birmingham.
1851. Rogers, Ebenezer, Abercarn, near Newport, Monmouthshire.
1853. Rogers, Jonathan, Pontypool Iron Works, near Newport, Monmouthshire.
1851. Rolinson, Thomas, Wellington Road, Dudley.
1853. Ronayne, Joseph P., Engineer-in-Chief, Sierra Nevada Lake Water and Mining Company, (Post Office, San Francisco,) California: (or care of Timothy Mahony, 3 Camden Quay, Cork.)
1853. Ross, John, Messrs. Brown Marshalls and Co., Britannia Carriage Works, Birmingham.
1856. Rouse, Frederick, Great Northern Railway, Locomotive Department, Leeds.
1857. Routledge, William, New Bridge Foundry, Salford, Manchester.
1856. Russel, Robert, Resident Engineer, Manchester Sheffield and Lincolnshire Railway, Manchester.
1847. Russell, John Scott, F.R.S., 20 Great George Street, Westminster, S.W.

1848. Samuel, James, 26 Great George Street, Westminster, S.W.
1857. Samuelson, Alexander, Scott Street Foundry, Hull.
1857. Samuelson, Martin, Scott Street Foundry, Hull.
1858. Scott, Joseph, Messrs. R. and W. Hawthorn, Forth Banks, Newcastle-on-Tyne.
1848. Scott, Michael, 26 Great George Street, Westminster, S.W.
1857. Selby, George Thomas, Smethwick Tube Works, Birmingham.
1850. Shanks, Andrew, 6 Robert Street, Adelphi, London, W.C.
1856. Shelley, Charles Percy Bysshe, 21 Parliament Street, Westminster, S.W.
1851. Siemens, Charles William, 7 John Street, Adelphi, London, W.C.
1847. Sinclair, Robert, Locomotive Superintendent, Eastern Counties Railway, Stratford, London, E.
1857. Sinclair, Robert Cooper, Tame Valley Colliery, Wilnecote, near Tamworth.
1853. Slaughter, Edward, Avonside Iron Works, Bristol.
1854. Smith, George, Wellington Road, Dudley.
1847. Smith, Henry, Spring Hill Works, Birmingham.
1858. Smith, Isaac, 36 Lancaster Street, Birmingham.
1847. Smith, Josiah Timmis, Windmill End Furnaces, Dudley.
1857. Smith, William, 18 Salisbury Street, Adelphi, London, W.C.
1857. Snowdon, Thomas, Tees Side Iron Works, Middlesborough.
1858. Sörensen, Bergerius, Horten Dockyard, Norway.
1853. Spencer, Thomas, Old Park Works, near Shiffnal.
1854. Spencer, Thomas, Newburn Steel Works, Newcastle-on-Tyne.
1857. Spray, Frederic George, St. Petersburgh.
1855. Stenson, William, Jun., Whitwick Collieries, near Ashby-de-la-Zouch.
1851. Stewart, John, Blackwall Iron Works, Russell Street, Blackwall, London, E.
1857. Stokes, Lingard, Locomotive Superintendent, East Indian Railway, Howrah, Calcutta.

1858. Taylor, James, Clarence Iron Works, Leeds.
1858. Taylor, James, Britannia Works, Cathcart Street, Birkenhead.
1858. Taylor, Thomas John, Earsdon, near Newcastle-on-Tyne.
1848. Thompson, Isaac, Messrs. Kitson and Co., Airedale Foundry, Leeds.
1851. Thompson, James, Pin Mill, Ardwick, Manchester.
1857. Thompson, John Taylor, Messrs. R. and W. Hawthorn, Forth Banks, Newcastle-on-Tyne.
1857. Thompson, Robert, Haigh Foundry, near Wigan.
1852. Thomson, George, Crookhay Iron Works, Westbromwich.
1858. Thomson, William, Jun., Railway Foundry, Normanton.
1848. Thornton, Robert, St. Leonard's Iron Works, Edinburgh.
1847. Thornton, Samuel, Bradford Street, Birmingham.
1857. Tomlinson, Joseph, Jun., Locomotive Superintendent, Taff Vale Railway, Cardiff.
1856. Tosh, George, Locomotive Superintendent, Maryport and Carlisle Railway, Maryport.
1856. Truss, Thomas, Shrewsbury and Chester Railway, Carriage Department, Chester.
1849. Turton, Thomas Burdett, Sheaf Works, Sheffield.
1856. Tyler, Capt. Henry Wheetley, R.E., Railway Department, Board of Trade, Whitehall, London, S.W.

1856. Vernon, John, Iron Ship Building Yard, Brunswick Dock, Liverpool.

1856. Waddington, John, New Dock Iron Works, Leeds.
1856. Waddington, Thomas, New Dock Iron Works, Leeds.
1847. Walker, Thomas, Patent Shaft Works, Wednesbury.
1856. Waller, William, Messrs. John Gray and Co., Uddingston, near Glasgow.
1856. Wardle, Charles Wetherell, Boyne Engine Works, Hunslet, Leeds.
1852. Warham, John R., Iron Works, Burton-on-Trent.
1847. Weallens, William, Messrs. R. Stephenson & Co., South Street, Newcastle-on-Tyne.
1857. West, Frank W. S., East Indian Railway, Calcutta.
1856. Wheeldon, Frederick R., Highfields Engine Works, Bilston.
1847. Whitworth, Joseph, Chorlton Street, Manchester.
1847. Williams, Richard, Patent Shaft Works, Wednesbury.
1850. Williams, Walter, Jun., Albion Iron Works, Westbromwich.
1858. Williams, William, London and North Western Railway, Locomotive Department, Crewe.
1856. Wilson, Edward, Oxford Worcester and Wolverhampton Railway, Worcester.
1858. Wilson, Edward Brown, 36 Parliament Street, Westminster, S.W.
1857. Wilson, John, Spring Works, Hill Top, Westbromwich.
1852. Wilson, Joseph W., Seymour Chambers, Duke Street, Adelphi, London, W.C.
1857. Wilson, Robert, Bridgewater Foundry, Patricroft, near Manchester.
1848. Wingate, Thomas, Whiteinch Foundry, Partick, near Glasgow.

1858. Wood, Nicholas, Hetton Hall, Hetton, near Fence Houses.
1848. Woodhouse, Henry, London and North Western Railway, Stafford.
1851. Woodhouse, John Thomas, Midland Road, Derby.
1858. Woods, Hamilton, Exchange Buildings, Grainger Street, Newcastle-on-Tyne.
1848. Wright, Henry, Saltley Works, Birmingham.
1848. Wright, Joseph, Saltley Works, Birmingham.
1853. Wymer, Francis W., 5 Heaton Terrace, Elwick's Lane, Newcastle-on-Tyne.

1856. Yarrow, Thomas, Locomotive Superintendent, Scottish North Eastern Railway, Arbroath.
1856. Young, John, Hope Villa, Woodhouse Lane, Leeds.

LIFE MEMBERS.

1853. Maudslay, Henry, 4 Cheltenham Place, Lambeth, London, S.
1848. Penn, John, The Cedars, Lee, Blackheath, Kent, S.E.
1847. Stephenson, Robert, M.P., 24 Great George Street, Westminster, S.W.

HONORARY MEMBERS.

1848. Branson, George, Belmont Row, Birmingham.
1858. Budden, William Humphryes, Messrs. R. Stephenson and Co., South Street, Newcastle-on-Tyne.
1851. Clare, Thomas Deykin, Midland Railway Station, Lawley Street, Birmingham.
1848. Crosby, Samuel, Leek Street, Birmingham.
1850. Gwyther, Edwin, Belmont Row, Birmingham.
1857. Hawkes, William, Eagle Foundry, Broad Street, Birmingham.
1858. Lawton, Benjamin C., Grainger Street, Newcastle-on-Tyne.
1856. Marshall, John, Low Moor Iron Works, near Bradford, Yorkshire.
1856. Moss, Henry E., 2 Rumford Place, Liverpool.
1848. Peto, Sir Samuel Morton, Bart., 9 Great George Street, Westminster, S.W.
1856. Pettifor, Joseph, Midland Railway, Derby.
1856. Singleton, William, Dock Street, Leeds.
1848. Warden, William Marston, Edgbaston Street, Birmingham.
1858. Waterhouse, Thomas, Claremont Place, Sheffield.

HONORARY LIFE MEMBERS.

1849. Hodgkinson, Eaton, F.R.S., 44 Drayton Grove, Brompton, London, S.W.
1848. MacGregor, James, 25 Eccleston Square, London, S.W.

GRADUATES.

1850. Glydon, George, Spring Hill Tube and Metal Works, Eyre Street, Birmingham.
1851. Potts, J. Thorpe, 4 Crescent Place, Camberwell Grove, Camberwell, Surrey, S.

PROCEEDINGS.

January 28, 1858.

The Eleventh Annual General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Thursday, 28th January, 1858; Joseph Whitworth, Esq., President, in the Chair.

The Minutes of the last General Meeting were read by the Secretary, and were confirmed.

The Secretary then read the following

ANNUAL REPORT OF THE COUNCIL.
1858.

The Council have much pleasure, on this occasion of the Eleventh Anniversary of the Institution, in congratulating the Members on the prosperous condition and successful progress of the Institution.

The Financial statement of the affairs of the Institution for the year ending 31st December, 1857, shows a balance in the Treasurer's hands of £407 12*s.* 7*d.*, after the payment of the accounts due to that date. The Finance Committee have examined and checked the receipts and payments of the Institution for the last year, 1857, and report that the following Balance Sheet rendered by the Treasurer is correct.

(*See Balance Sheet appended.*)

The Council report with great satisfaction the continued increase in the number of Members that has taken place during the last year, the total number of Members of all classes for the year being 301, of whom 15 are Honorary Members, and 2 are Graduates.

The Council have to report the decease of three Members of the Institution during the past year, namely:—

Edward Elwell, . . .	Wednesbury.
George Hennet, . . .	London.
David M. Roche, . . .	Calcutta.

The Council have the pleasure of acknowledging the following Donations to the Library of the Institution during the past year, and expressing their thanks to the Donors for the valuable and acceptable additions they have presented to the Library. The Council wish to urge especially on the attention of the Members the important advantage to the Institution of obtaining a good collection of Engineering Books, Drawings, and Models, for the purpose of reference by the Members personally or by correspondence; and they refer with much gratification to the valuable addition made in the past year to the Library of Reference by one of the Vice-Presidents, and trust that this highly desirable object will be supported by the Members generally, that by their united aid it may be efficiently accomplished.

LIST OF DONATIONS TO THE LIBRARY.

Portfolio of Engineering Engravings; from the Ecole Impériale des Ponts et Chaussées.

Donation of Books from Mr. Henry Maudslay:—

- Buchanan's Millwork and Machinery, by George Rennie, 2 Vols.
- The Marine Steam Engine, by Main and Brown.
- Tredgold on the Steam Engine—Marine Engines, 2 Vols.
- Screw Propellers and their Steam Engines, by J. W. Nystrom.
- The Engineer and Machinist's Assistant, 2 Vols.
- The Imperial Cyclopædia of Machinery, by William Johnson.
- Smeaton's Reports, 2 Vols.
- Dud Dudley's Metallum Martis.
- The Iron Manufacture of Great Britain, by William Truran.

On the Application of Cast and Wrought Iron to Building Purposes, by William Fairbairn; from the Author.

Description of the Sliding Caisson at Keyham Dockyard, by William Fairbairn; from the Author.

Treatise on Cast and Wrought Iron Bridges and Girders, by William Humber; from the Author.

Life of George Stephenson, by Samuel Smiles; from the Author.
Memorials of James Watt; from Mr. Robert Napier.
On the Iron Question, by Joseph Hall; from Mr. William Hall.
Report of the French Exhibition of 1855; from M. Burel.
Transactions of the Institution of Civil Engineers, 16 volumes complete from the commencement; from the Institution.
Transactions of the North of England Institute of Mining Engineers, Vol. IV.; from the Institute.
Transactions of the Royal Scottish Society of Arts; from the Society.
Memoirs of the Literary and Philosophical Society of Manchester, Vol. XIV.; from the Society.
Dalton's Meteorology; from do.
Dalton's New System of Chemistry, Vol. I., and Vol. II. Part I.; from do.
Journal of the Society of Arts; from the Society.
The Artizan Journal; from the Editor.
The Civil Engineer and Architect's Journal; from the Editor.
The London Journal of Arts; from the Editor.
The Mechanics' Magazine; from the Editor.
The Practical Mechanic's Journal; from the Editor.
The Engineer; from the Editor.
The Mining Journal; from the Editor.
The Railway Record; from the Editor.
Specimens of a Double Elliptical Convex-Plate Spring; from Mr. John Wilson.
Specimen of a Pressure Gauge; from Mr. John Inshaw.
Specimens of a new process of Steel Manufacture; from Mr. T. W. Dodds.

The Council have great satisfaction in referring to the large number of papers that have been brought before the Meetings of the Institution during the year, and the practical value and interest of many of the communications, which form a valuable addition to the Proceedings. The Council request the special attention of the Members to the importance of their aid and co-operation in carrying out the objects of the Institution and maintaining its advanced position, by contributing papers on Engineering subjects that have come under their observation, and communicating the particulars and results of executed works and practical experiments that may be serviceable and interesting to the Members; and the Council invite communications upon the subjects in the list appended, and other subjects advantageous to the Institution.

The following Papers have been read at the Meetings during the last year:—

On the Theory of Pile Driving, with description of an improved Steam Pile Driving Machine; by Mr. Michael Scott, of London, and Mr. Andrew John Robertson, of Blyth.

On the Manufacture of Charcoal and Coke; by Mr. Ebenezer Rogers, of Abercarn.

On the Application of Steam Power to Agricultural Purposes (third paper); by Mr. William Waller, of Lincoln.

On Steam Cultivation; by Mr. John Fowler, Jun., of London.

Description of improved Machinery for Rounding, Surfacing, and Shaping Wood; by Mr. Joseph W. Wilson, of Banbury.

On Tubular Wrought Iron Cranes; with description of the 60 Ton Tubular Wrought Iron Crane recently erected at Keyham Dockyard, Devonport; by Mr. William Fairbairn, of Manchester.

On a new Water Connexion between locomotive engines and tenders; by Mr. James Fenton, of Bradford.

On a new construction of Furnace, particularly applicable where intense heat is required; by Mr. C. William Siemens, of London.

Description of the large Blowing Engine and new Rolling Mill at Dowlais Iron Works; by Mr. William Menelaus, of Dowlais.

On the Relative Evaporating Power of Brass and Iron Tubes; by Mr. George Tosh, of Maryport.

Description of an Apparatus for the Prevention of Smoke in steam boiler and other furnaces; by Mr. William B. Johnson, of Manchester.

Description of an improved construction of Upright Steam Boilers; by Mr. Thomas Dunn, of Manchester.

On a Standard Decimal Measure of Length for Mechanical Engineering Work, &c.; by the President, Joseph Whitworth, Esq.

On the Saving of Dead Weight in Passenger Trains; by Mr. Charles Fay, of Manchester.

On improvements in Steel Manufacture, and its application to railway and other purposes; by Mr. Thomas W. Dodds, of Rotherham.

On recent improvements in Water Meters; by Mr. Benjamin Fothergill, of Manchester.

Description of a Safety Escape Pipe for steam boilers; by Mr. John Ramsbottom, of Manchester.

Description of a new Hydraulic Engine; by Mr. David Joy, of Leeds.

On Balancing the Valves of Steam Engines; by Mr. Charles Beyer, of Manchester.

Description of an Apparatus for Economising Fuel; by Mr. William G. Craig, of Manchester.

Description of an improved Pressure Gauge; by Mr. John Inshaw, of Birmingham.

On an improved construction of Safety Valves for steam boilers; by Mr. James Clarkson Kay, of Bury.

Description of a new Convex-Plate Laminated Spring; by Mr. John Wilson, of Westbromwich.

Description of Naylor's Double-Acting Steam Hammer; by Mr. Charles Markham, of Derby.

On Lighting Railway Trains with Gas, with description of Mr. T. J. Thomson's System; by Mr. James Kitson, of Leeds.

Description of Watson's Ventilating Apparatus for Buildings, &c.; by Mr. Samuel Thornton, of Birmingham.

The Council have particular pleasure in referring to the very successful and interesting meeting of the Institution held in Manchester in the summer of last year at the time of the Exhibition of Art Treasures, and in expressing their thanks to the Local Committee, and especially to their Secretary Mr. Benjamin Fothergill, for the excellent and spirited reception that was given to the Members of the Institution on that occasion; and the Council anticipate important advantages to the Institution from the continuance of such meetings, both there and in other districts of the country.

The President, Vice-Presidents, and Officers of the Institution, and five of the Members of the Council in rotation, will go out of office this day, according to the rules of the Institution; and the ballot will be taken at the present annual meeting for the election of the Officers and Council for the ensuing year.

SUBJECTS FOR PAPERS.

Steam Engine Boilers, particulars of construction—form and extent of heating surface—relative value of radiant surface in effect and economy—cost—consumption of fuel—evaporation of water—pressure of steam—density and heat of steam—superheated steam—pressure gauges—safety valves—water gauges—explosion of boilers, and means of prevention—effects of heat on the metal of boilers, low pressure and high pressure—incrustation of boilers, and

means of prevention—evaporative power and economy of different kinds of fuel, coal, wood, charcoal, peat, patent coal, and coke—moveable grates, and smoke-consuming apparatus, facts to show the best plan, and results of working—plans for heating feed water.

Steam Engines—expansive force of steam, and best means of using it—power obtained by various plans—comparison of double and single cylinder engines—combined engines—compound cylinder engines—comparative advantages of direct-acting and beam engines—engines for manufacturing purposes—horizontal and vertical—condensing and non-condensing—governors—valves, bearings, &c.—indicator figures from engines, with details of useful effects, consumption of fuel, &c.—contributions of indicator figures for reference in the Institution.

Pumping Engines, particulars of various constructions—size of cylinder and degree of expansion—strokes per minute, and horse power—number and size of pumps, and strokes per minute—comparison of double-acting and single-acting pumping engines—construction of pumps—plunger pumps—bucket pumps—particular details of different valves—application of pumps—fen-draining engines—comparative advantages of scoop wheels and centrifugal pumps, lifting trough, &c.

Blast Engines, best kind of engine—size of cylinder, strokes per minute, and horse power—details of boilers—size of blowing cylinder, and strokes per minute—pressure of blast, and means of regulation—construction of valves—improvements in blast cylinders—rotary blowing machines—indicator diagrams from air main and steam cylinder.

Marine Engines, power of engines in proportion to tonnage — different constructions of engines—dynamical effect compared with indicator figures—comparative economy and durability of different boilers, tubular boilers, flat flue boilers, &c.—weight of machinery and boilers—kind of paddle wheels—speed obtained in British war steamers, in British merchant steamers, and in Foreign ditto, with particulars of the construction of engines with paddle wheels, &c.—screw propellers, particulars of different kinds, improvements in form and position, number of arms, material, means of unshipping, bearings, horse power applied, speed obtained, section of vessel—iron and wood ships, details of construction, lines, tonnage, cost, &c.

Rotary Engines, particulars of construction and practical application—details of results of working.

Locomotive Engines, express, passenger, and luggage engines—particulars of construction, details of experiments, and results of working—consumption of fuel—use of coal—consumption of smoke—heating surface, length and diameter of tubes—experiments on size of tubes and blast pipe—expenses of working and repairing—construction of pistons, valve gear, expansion gear, &c.—indicator diagrams.

AGRICULTURAL ENGINES, details of construction and results of working—duty obtained—application of machinery and steam power to agricultural purposes —barn machinery—field implements—traction engines and machinery.

CALORIC ENGINES—engines worked by Gas, Gun-cotton, or other explosive compounds—Electro-magnetic engines—particulars and results.

HYDRAULIC ENGINES, particulars of application and working—hydraulic rams.

WATER WHEELS, particulars of construction and dimensions—form and depth of buckets—head of water, velocity, percentage of power obtained—turbines, construction and practical application, power obtained, comparative effect and economy.

WIND MILLS, particulars of construction—number of sails, surface and form of sails—velocity, and power obtained—average number of days' work per annum.

CORN MILLS, particulars of improvements—power employed—application of steam power—results of working with an air blast and small stones—advantages of regularity of motion.

SUGAR MILLS, particulars of construction and working—results of the application of the hydraulic press in place of rolls—construction and working of evaporating pans.

SAW MILLS, particulars of construction—mode of driving—power employed—particulars of work done—best speeds for vertical and circular saws—form of saw teeth—saw mills for cutting ship timbers—veneer saws—endless band saws.

OIL MILLS, facts relating to the construction and working, by stampers, by screw presses, and by hydraulic presses—particulars of crushing rollers.

COTTON MILLS, information respecting the construction and arrangement of the machinery—power employed, and application of power—cotton presses, mode of construction and working, power employed—improvements in spinning and carding machinery, &c.

MACHINERY for manufacturing Flax, both in the natural length of staple and when cut.

ROLLING MILLS, improvements in machinery for making iron and steel—mode of applying power—steam hammers—piling of iron—plates—fancy sections —arrangement and speed of rolls—length of bar rolled.

STAMPING AND COINING MACHINERY, particulars of improvements, &c.

PAPER-MAKING AND PAPER-CUTTING MACHINES, ditto ditto

PRINTING MACHINES, ditto ditto

CALICO-PRINTING AND BLEACHING MACHINERY, ditto ditto

WATER PUMPS, facts relating to the best construction, means of working, and application—best forms—velocity of piston—construction of valves.

AIR PUMPS, ditto ditto ditto

HYDRAULIC PRESSES, facts relating to the best construction, means of working, and application.

ROTARY AND CENTRIFUGAL PUMPS, ditto ditto ditto

Fire Engines, facts relating to the best construction, means of working, and application.

Sluices and Sluice Cocks, ditto ditto ditto

Cranes—Steam Cranes, Hydraulic Cranes, Pneumatic Cranes, ditto

Lifts for raising Trucks, &c. ditto ditto ditto

Lathes, Planing, Boring, and Slotting Machines, &c., particulars of improvements—description of new self-acting tools.

Wood-working Machines, morticing, planing, rounding, and surfacing.

Toothed Wheels, best construction and form of teeth—results of working—power transmitted—method of moulding.

Driving Belts and Straps, best make and material, leather, gutta percha, rope, wire, chain, &c.—comparative durability, and results of working—power communicated by certain sizes—frictional gearing, construction and driving power obtained—friction clutches—shafting and couplings.

Dynamometers, construction, application, and results of working.

Strength of Materials—facts relating to experiments on ditto, and general details of the proof of girders, &c.—girders of cast and wrought iron, particulars of different constructions, and experiments on them—best forms and proportions of girders for different purposes—best mixture of metal—mixtures of wrought iron with cast.

Durability of Timber of various kinds—best plans for seasoning timber and cordage—results of various processes—comparative durability of timber in different situations.

Corrosion of Metals by salt and fresh water, and by the atmosphere, &c.—facts relating to corrosion, and best means of prevention—means of keeping ships' bottoms clean—galvanic action, nature, and preventives.

Alloys of Metals—facts relating to different alloys.

Friction of various Bodies—facts relating to friction under ordinary circumstances—friction of iron, brass, copper, tin, wood, &c.—proportion of weight to rubbing surface—best forms of journals, and construction of axle boxes, &c.—lubrication, best materials, and means of application, and results of practical trials—best plans for oil tests.

Iron Roofs, particulars of construction for different purposes—durability in various climates and situations—comparative cost, weight, and durability—roofs for slips of cast iron, wrought iron, timber, &c.—best construction, form, and material—details of large roofs, and cost.

Fire-proof Buildings, particulars of construction—most efficient plan—results of trials.

Chimney Stacks of large size—particulars, form, force of draught, mode of building, cheapest construction, &c.

Bricks, manufacture and durability—hollow bricks, fire bricks, and fire clay—perforated bricks, cost of manufacture, and advantages—machines for brick making.

Gas Works—best form, size, and material for retorts—construction of retort ovens—quantity and quality of gas from different coals—oil gas, water gas, &c.—improvements in purifiers, condensers, and gasholders—wet and dry gas meters,—pressure of gas, gas exhauster—gas pipes, strength and durability, and construction of joints—proportionate diameter and length of gas mains, and velocity of the passage of gas—experiments on ditto, and on the friction of gas in mains, and loss of pressure.

Water Works—facts relating to water works—application of power, and economy of working—proportionate diameter and length of pipes—experiments on the discharge of water from pipes, and friction through pipes—strength and durability of pipes, and construction of joints—relative advantages of stand pipes and air vessels—water meters, construction and working.

Well Sinking, and Artesian Wells, facts relating to—boring tools, construction and mode of using.

Coffer Dams and Piling, facts relating to the construction.

Piers, fixed and floating, and pontoons, ditto ditto

Pile Driving Apparatus, particulars of improvements—use of steam power—particulars of working—weight of ram and height of fall, total number of blows required—vacuum piles—compressed air system.

Dredging Machines, particulars of improvements—application of dredging machines—power required and work done.

Diving Bells and Diving Dresses, facts relating to the best construction.

Light-houses, cast iron and wrought iron, ditto ditto

Mining Operations—facts relating to mining—means of ventilating mines—use of ventilating machinery—safety lamps—lighting mines by gas—mode of raising materials—safety guides—winding machinery—mode of breaking, pulverising, and sifting various descriptions of ores.

Blasting—facts relating to blasting under water, and blasting generally—use of gun-cotton, &c.—effects produced by large and small charges of powder—arrangement of charges.

Blast Furnaces—consumption of fuel in different kinds—burden, make, and quality of metal—pressure of blast—horse power required—economy of working—improvements in manufacture of iron—comparative results of hot and cold blast—use of waste gases.

Puddling Furnaces, best forms and construction—worked with coal, charcoal, &c.

Heating Furnaces, best construction—consumption of fuel, &c:

Converting Furnaces—manufacture of steel—construction of furnaces—casehardening, &c.—converting materials employed.

Smiths' Forges, best construction—size and material—power of blast—hot blast, &c.—construction of tuyeres.

Smiths' Fans, and Fans generally, best construction, form of blades, &c.—facts relating to power employed and percentage of effect produced—pressure and quantity of air discharged—size and construction of air mains.

Coke and Charcoal, particulars of the best mode of making, and construction of ovens, &c.—evaporating power of different varieties.

Railways—construction of permanent way—section of rails, and mode of manufacture—experiments on rails, deflection, deterioration, and comparative durability—material and form of sleepers, size and distances—improvements in chairs, keys, and joint fastenings—permanent way for hot climates.

Switches and Crossings, particulars of improvements, and results of working—advantages obtained by steeling points and tongues.

Turn-Tables, particulars of various constructions and improvements.

Signals for stations and trains, and self-acting signals.

Electric Telegraphs, improvements in construction and insulation—mode of laying.

Railway Carriages and Wagons, details of construction—proportion of dead weight.

Breaks for carriages and wagons, best construction.

Buffers for carriages, &c., and station buffers—different constructions and materials.

Springs for carriages, &c.—buffing, bearing, and draw springs—particulars of different constructions and materials, and results of working.

Railway Wheels, wrought iron, cast iron, and wood—particulars of different constructions, and results of working—comparative expense and durability—wrought iron and steel tyres, comparative economy, and results of working—solid wrought iron wheels.

Railway Axles, best description, form, material, and mode of manufacture—comparison of solid and hollow axles.

The communications should be written on foolscap paper, on one side only of each page, leaving a clear margin on the left side for binding, and they should be written in the third person. The drawings illustrating the paper should be on so large a scale as to be clearly visible to the meeting at the time of reading the paper, or enlarged diagrams should be sent for the illustration of any particular portions.

INSTITUTION OF MECHANICAL ENGINEERS.

BALANCE SHEET.

For the year ending 31*st December*, 1857.

Cr.	£	*s.*	*d.*
By Balance 31st December, 1856.	298	5	9
„ Subscriptions from 13 Members in arrear . . .	39	0	0
„ ditto from 248 Members for 1857.	744	0	0
„ ditto from 2 Graduates do.	4	0	0
„ ditto from 63 New Members, Entrance Fees . .	126	0	0
„ ditto from 1 Graduate, do.	1	0	0
„ ditto from 5 Members in advance for 1858 . . .	15	0	0
„ Sale of Extra Reports	54	12	8
„ Interest from Bank	13	18	11
	£1295	17	4

Dr.	£	*s.*	*d.*
To Printing and Engraving Reports of Proceedings .	299	14	6
„ Stationery and Printing	27	15	10
„ Office Expenses and Petty Disbursements . . .	25	5	2
„ Expenses of Meetings	11	18	8
„ Furniture and Fittings	19	5	10
„ Travelling Expenses	5	16	8
„ Parcels	3	8	0
„ Postages.	27	16	1
„ Salary	350	0	0
„ Rent and Taxes.	117	4	0
„ Balance 31st December, 1857	407	12	7
	£1295	17	4

(Signed) J. E. CLIFT, EDWARD JONES, } Finance Committee.

28*th January*, 1858.

The Chairman moved that the Report of the Council be received and adopted, which was passed.

The Chairman announced that the Ballot Papers had been opened by the Committee appointed for the purpose, and the following Officers and Members of Council were duly elected for the ensuing year:—

PRESIDENT.

John Penn,	London.

VICE-PRESIDENTS.

William Fairbairn,	Manchester.
James Fenton,	Bradford.
Benjamin Fothergill,	Manchester.
Henry Maudslay,	London.
John Ramsbottom,	Crewe.
Joseph Whitworth,	Manchester.

COUNCIL.

In addition to the ten Members remaining in office.

Charles Beyer,	Manchester.
Robert Hawthorn,	Newcastle-on-Tyne.
James Kitson,	Leeds.
James E. McConnell,	Wolverton.
William Weallens,	Newcastle-on-Tyne.

TREASURER.

Henry Edmunds,	Birmingham.

SECRETARY.

William P. Marshall,	Birmingham.

The following New Members were also elected:—

MEMBERS.

William George Armstrong,	Newcastle-on-Tyne.
Charles Atkinson,	Sheffield.
Henry Burn,	Derby.
Pierre A. H. Guerguin,	Paris.
John A. Haswell,	Gateshead.
John Hosking,	Gateshead.
William Naylor,	Norwich.
William Thomson, Jun.,	Normanton.

Mr. J. Fenton proposed that a special vote of thanks be given to the Council of the Manchester Mechanics' Institution, for their kindness and liberality in granting the free use of their rooms for the Manchester Meeting of this Institution, and the facilities afforded by them in carrying out the arrangements for the meeting. The motion was seconded by Mr. E. A. Cowper, and carried unanimously.

The following Paper, by Mr. Robert Jobson, of Wordsley, was then read :—

ON AN IMPROVED SYSTEM OF MOULDING AND CASTING.

Amongst the few roads left open for improvement in the economy of moulding, increased rapidity of production appears to be the most available; but advantage can rarely be taken of this except where there is great repetition in the article required, as in the case of railway chairs in all their varieties, shot, shells, castings for agricultural implements, pipes, troughs, stove and fender castings, &c.; it is to this class of work accordingly that the moulding machine described in the present paper is more specially applicable.

The Moulding Machine is shown in Figs. 1, 2, and 3, Plates 1 and 2. Fig. 1, Plate 1, is a side elevation with the side portion of the frame removed, showing the last position of the machine, when the mould is ready for removal. Fig. 2 is a vertical section of the machine in the opposite direction, corresponding to a front elevation, drawn in the last position like Fig. 1. Fig. 3, Plate 2, is a side elevation showing the machine in the first position, in which the mould box is filled and rammed up.

AA is the moulding table or bed, consisting of a rectangular cast iron box, open at top and bottom, and furnished with a large cylindrical axis BB at each end, 6 inches diameter, turning in bearings on the side frames CC. The axes are prolonged at the ends, and counterbalance weights DD attached to them by arms, which can be readily adjusted by lengthening or shortening so as to balance the table with the mould upon it, leaving it free to turn upon the axes. The table turns half round, as shown by the two positions in Figs. 1 and 3, being prevented from turning further by stops EE upon the ends of the moulding table, which catch in notches on the top of the frame C. On the top of the table A a plate F is fixed by screw bolts, carrying the moulding box G which is secured upon it by two inclined catches with handles HH, the plate F forming the ramming board upon which the pattern I is

fixed and the moulding sand rammed upon it in the ordinary way. The machine is shown as arranged for moulding 8 inch shells, the pattern I being a hemisphere; any other pattern or form of flask within the limits of the size of the machine can however be readily employed, the only preparation requisite being to fix each pattern upon a bottom plate having bolt holes to correspond with those in the top of the moulding table. This arrangement is so simple that after the machine has been moulding shells it can be changed and got to work again at moulding railway chairs or other articles within 10 minutes' time.

As soon as the sand is rammed, the cover plate K is put on the box by sliding it on the inclined snugs which hold it fast; the whole is then turned over with the moulding table into the reversed position, as in Fig. 1, this being effected by the simple pressure of pushing home the cover plate K, since the whole is balanced and turns freely upon the axes. In moulding shells, the pattern I is then withdrawn from the mould sufficiently to make it clear the sand, by means of the screw and hand wheel L. A rising platform M, which slides in vertical grooves in the side frames CC, is then brought up by means of the lever O to touch the cover plate of the box which is now at the underside, and the box is liberated from the moulding plate by releasing the two catches HH simultaneously by means of the second handles NN fixed on the other ends of the spindles for this purpose. The whole is then in the position shown by the dotted lines in Fig. 2, and the platform M now descends by means of the additional weight upon it to the bottom position in Fig. 2, the platform being counterpoised by the balance weights PP. The mould is then removed by sliding it off the platform on to a little railway placed at the same level; and the machine is made ready for repeating the operation by screwing down the pattern to its right place, and turning back the moulding table to its former position, ready to receive a second empty box.

The principle carried out in this machine, of turning over the whole moulding table with the mould and pattern upon it undisturbed, has the effect of saving all labour of lifting the moulds; so that boys, who are sufficient for all the actual moulding work, are able to complete the process, instead of men being required to lift the heavy weights. An advantage in average quality of work and saving of wasters is obtained by avoiding all handling and risk of disturbing the moulds

in lifting them off; they simply slide along a little smooth railway from the moulding machine to the casting ladle, which is fixed within 7 feet 6 inches distance from the moulding machine centre to centre. A very important point is also gained by always replacing the pattern in its first position while still inverted, thus preventing any particles of sand from interfering with the working parts of the pattern. It is an essential point in machinery applied to such purposes as the present, that it should be arranged so as to keep in good order for long continued regular work, without requiring any care or nicety in management that would interfere at all with the roughness of manipulation inseparable from such work where expedition and economy of manufacture combined with accuracy in the castings are the objects to be accomplished; and the present machine has been found completely satisfactory in this respect. The result of the working of the moulding machine is so successful that one mould consisting of two railway chairs is readily completed every minute on one machine; and the machine is found to keep so completely in working order that the regular day's work of 10 hours produces from 1000 to 1100 chairs, being at the average rate throughout of 2 chairs per minute. This extraordinary rapidity of moulding by the machine could not be made fully available with the ordinary means of casting, on account of the large floor space required for casting with the necessary rapidity, and the consequent delay and expense attending the removal of the moulds over that space; and a great objection experienced at first in regard to economy of work was the large number of moulding boxes to keep even one machine going at the full rate. To meet these difficulties a casting apparatus was designed by the writer, which is fixed close to the moulding machine; this is capable of filling the moulds as fast as they leave the machine, so that no loss of time or space occurs; and within two or three minutes the whole operation of moulding and casting is completed in each case, and the box laid out in the open air to cool, ready for emptying and using again on the machine within about 6 minutes' time.

The Casting Apparatus is shown in Figs. 4 and 5, Plate 2; Fig. 4 being a plan and Fig. 5 a side elevation of the apparatus.

The ladle A is placed in a standard frame B upon the floor, the sides of which partly embrace the front of the ladle, as shown in the

plan Fig. 4, and carry a spindle C at their extremities, which passes through two corresponding lugs fixed on the front of the ladle just below the lip. This spindle C forms an axis upon which the ladle turns when pouring, and the ladle is lifted by means of a shaft D fixed across the centre of the bottom and connected by links to the two levers EE, which are fixed on the cross shaft F and moved by the hand levers G. The weight of the loaded ladle is counterpoised by balance weights H attached by chains hooked on to each end of the shaft D and carried over pulleys upon the roof timbers or frame of the ladle. From the position of the axis C on which the ladle turns, the lip of the ladle follows the direction of the stream of metal all the time that the ladle is being turned to its extreme position shown by the dotted lines, so that the position of the stream of metal is stationary in all positions of the ladle; the several moulds are therefore only required to be brought to the same spot in succession, and the metal can be poured in at once without any delay for adjustment of position, the moulds being filled as fast as they can be brought up to the ladle from the moulding machine. The command over the movement of the ladle given by the long lever G makes the pouring of the metal very steady; and the whole being nearly balanced, the caster tilts the ladle with one hand whilst he skims the metal for himself with the other. A supply of fresh metal is brought from the cupola at regular intervals by a couple of labourers with an ordinary double-handled ladle.

To define the limits of any particular mode of moulding is somewhat difficult; but some conclusion may be arrived at by a comparison between the plan above described with the new moulding machine and the old system.

In casting railway chairs by the old system it was considered a good day's work to obtain 300 castings from one man and his boys, and with the best plan the average does not exceed 480 per day. To produce this quantity the man who rams up the bottom box has to lift the following weights :—

Bottom Box	26 lbs.
Patterns	45 lbs.
Sand	48 lbs.
Ramming board	12 lbs.
Total,	131 lbs.

This total weight of 131 lbs. has to be divided by 2, as the box rests upon its edge while being turned over; therefore 131 lbs. divided by 2 = 65 lbs. After turning it over the man has to

Lift off the ramming board	12 lbs.
Draw the patterns	45 lbs.
Carry the box full of sand to the casting stage .	74 lbs.
Add 65 lbs. brought forward . . .	65 lbs.
Total,	196 lbs.

which multiplied by 240, the number of boxes moulded to produce 480 chairs, 2 chairs in each box, gives 47,040 lbs. or more than 20 tons to be lifted by the man during his day's work.

In the new moulding machine, by using the turn-over table, a man has been regularly making from 1000 to 1100 chairs per day, in producing which he had to lift only the empty bottom box and cover plate.

Bottom box	26 lbs.
Cover plate	9 lbs.
Total,	35 lbs.

which multiplied by 550, the average number of boxes moulded, 2 chairs in each box, gives 19,250 lbs. or only 9 tons to be lifted in making the larger quantity, against 20 tons in making the smaller quantity by the old plan, the latter requiring accordingly about $5\frac{1}{2}$ times as much labour in lifting per chair produced as is necessary with the machine.

With regard to the casting: by the ordinary plan of carrying the iron and pouring it into the moulds, for casting railway chairs, six men and three boys were required to each table, and a long length of rails, together with a much greater number of boxes; but by the new ladle one man is enabled to cast all that can be moulded on one table, and two metal carriers are sufficient for two tables; so that two men can in this department do the work of nine men and boys, and with less labour, since they have not to stand in a constrained position with a heavy weight, as they were compelled to do in filling the moulds by the ordinary hand ladles. Also the equality of the heat of the iron is greater from its being constantly supplied; and its purity is increased by being stirred up every time the hot metal is

poured into the ladle, which is a very important consideration in casting shot and shells. The regularity with which the process is carried on keeps the ground constantly clear, without bustle or confusion, and no one appears overworked.

The moulding table has been applied to moulding the wedges for Parson's railway chairs, weighing 4 lbs. each, 10 in a box; and the result has been the production of 5000 wedges per day from a pair of tables, while by the old process only between 900 and 1000 wedges per day were obtained. The writer understands that at Ipswich the machine has been applied to moulding bullock pans; and the result is that 4 times as many castings are produced, and of better quality than before.

The saving in boxes and in the breakage inseparable from the old system would, the writer considers, in a very short time pay for the moulding table, casting ladle, and all other extra outlay; and the common charges or incidental expenses are brought down to a minimum. The foundry room required for one set of apparatus for moulding and casting chairs is only 22 feet by 14 feet or about 300 square feet, thus enabling any foundry already built to produce at least 3 times as much work as before in the same floor space. No more skill is necessary for working the machine than can be taught in an hour, and strength is quite a secondary consideration; the cheapest class of labour is therefore available.

Mr. R. Jobson showed one of the moulding tables with railway chair patterns upon it, and specimens of chairs and wedges cast from moulds made by the machine.

Mr. J. Fenton enquired how many of the 8 inch shells had been moulded by the machine.

Mr. R. Jobson replied that the machine had not yet been worked for casting shells; it had been prepared for the purpose, but further proceedings had been stopped by the termination of the late war.

The Chairman asked how many of the machines were now at work altogether.

Mr. R. Jobson said he had had four of the machines at his own works, employed in moulding railway chairs, and there were eight more employed at Messrs. Ransomes and Sims' works at Ipswich.

Mr. A. B. Cochrane had seen the machine at work at Mr. Jobson's foundry, and could endorse all that had been represented in the paper as to its efficiency and success; he had seen chairs moulded by the machine when at regular work, and the number produced was accurately stated in the paper; he was much struck by the remarkable rapidity with which the operations of moulding and casting were effected. It was felt by all founders that one of the most advantageous points to be attained was the facility of carrying on work in the smallest possible space; this applied particularly to towns where land was valuable: hence the machine in question particularly recommended itself as an economiser of space. In many descriptions of castings he considered the machine highly useful: it effected neatness and cleanliness in carrying on the work; still more, it in a measure obviated the necessity for employing skilled labour. He felt confident that any one who had seen the machine in operation must be convinced that it formed a very important improvement in moulding, more especially where a great number of castings were required from the same pattern. He also felt satisfied that it would be found equally useful for general castings as for railway chairs.

Mr. R. Jobson observed that the machine afforded great facility for changing the pattern from one work to another with very little delay in getting it to work again. One of the machines was lately put to work in a foundry at Seraing near Liège for casting railway chairs, and its applicability to the patterns in ordinary use was seen at once; a pair of them was brought from the foundry and fixed to a board and then placed upon the moulding table, and the first chairs were produced within an hour and a half after starting to fit on the patterns.

The Chairman enquired what was the cost of a moulding machine of the size shown in the drawings, suitable for moulding shells or railway chairs.

Mr. R. Jobson said that the cost was about £11 for a machine of that size, independent of the patterns of the work to be moulded.

Mr. J. E. Clift asked how large a size of pattern could be moulded in the machine, and whether it would be applicable to moulding 9 feet gas and water pipes without any difficulty in turning over the moulding table with so great a weight upon it.

Mr. R. Jobson said that any pattern under 6 feet long could be readily moulded with the machine, and there was not any difficulty in turning over the moulding table with a heavy weight, the whole being so nearly balanced that the weight of work did not signify; the axes on which the table turned were 6 inches diameter, as large as the trunnions of a good sized cannon, and were therefore amply strong enough for carrying any required weight.

Mr. A. B. Cochrane thought the smaller sized pipes could be readily moulded in the machine with great expedition and accuracy.

Mr. B. Fothergill asked whether the machine had been tried for moulding small articles, such as the numerous small castings required in the cotton, woollen, and flax manufactures, where there was a great repetition in the castings, which were generally cast united in sprays to be separated after casting; such articles could be moulded with great rapidity and correctness by means of the machine, which was certainly a very ingenious and beautiful process of moulding.

Mr. R. Jobson replied that the machine had not yet been tried for that work, but it was very applicable to anything of the plate moulding kind; and it was evident that in such cases, as with large castings, the mould produced by the machine must be considerably more perfect than in hand work.

Mr. P. D. Bennett had seen the machine at work, and was much struck with the finished appearance of the castings produced from it, which was the more remarkable from the great rapidity with which the moulds were turned out. Great facility was given by the combination of the moulding and casting apparatus, with increased accuracy of work and saving of wasters; and he understood that in a special trial as many as 1300 good chairs had been moulded and cast in the ten hours with one machine.

Mr. B. Fothergill enquired how long the machine had been in use.

Mr. R. Jobson said it was about 15 months since the first machine was put to work.

The Chairman proposed a vote of thanks to Mr. Jobson for his paper, which was passed.

The following Paper, by Mr. Benjamin Fothergill, of Manchester, was then read :—

DESCRIPTION OF WRIGLEY'S FRICTION COUPLING FOR SHAFTING.

This plan of Friction Coupling, which is the invention of Mr. Francis Wrigley of Manchester, consists of a double set of powerful levers, each set forming what is called a knuckle joint, directly applied to a friction surface in motion, which is by that means brought into easy and gradual contact with another corresponding surface at rest, and there firmly held in position by the levers without any other retaining force. By the effect of this frictional contact any required amount of power may be transmitted from the prime mover to shafting, gearing, or other machinery, which has alternately to be set in motion or brought to rest; and this is accomplished silently, and without the slightest shock or concussion to any part of the shafting, gearing, or machinery.

The construction of this friction coupling is shown in Figs. 1 and 2, Plate 3. Fig. 1 is a front elevation, showing the external friction ring A, and the internal segmental friction blocks BB and double levers CC, with the method of connecting the levers to the internal friction blocks, and the mode of adjustment. Fig. 2 is a vertical section through the centre of the coupling, showing the double levers CC and their connection with the internal friction blocks BB, together with the side links or coupling bars D to the sliding box E, which moves on two fast keys or feathers let into the shaft F, and to which is applied the long forked lever G whereby the coupling is thrown in or out of gear.

The bevil wheel H, to which is secured by bolts the external friction ring A, is bored out to fit the shaft F, and runs free upon it. I is a strong circular disc keyed fast on the shaft F, on which are fitted the two segmental friction blocks BB, carried round by means of the snugs JJ cast on the disc I, which act as drivers as well as guides for the friction blocks B to slide on. KK are case-hardened bearings fitted into the friction blocks B, against which the circular ends of the levers C abut; LL are keeps fitted to the inside of the ends of the levers C, and kept in contact by the set screws M, for the purpose of bringing back the friction blocks when thrown out of gear. NN are the adjusting screws acting

against the case-hardened bearings K by an inclined plane, as shown in the lower half of Fig. 2, by means of which the double levers C can in effect be lengthened or shortened, so as to adapt the pressure between the friction surfaces to the power required to be transmitted. By this method of adjustment the slightest amount of wear on the friction surfaces or in the joints can be compensated for with the greatest accuracy.

When the friction surfaces are brought into permanent or working contact, they require no sustaining power to keep them there; for to accomplish this it is only necessary to bring the inner centres of the double levers C into line with their extreme centres, thereby forming a column having no tendency to move out of line one way or the other. In the transmission of power, say from 25 horse power upwards, it is considered advisable when convenient to work the forked lever G by means of a coarse pitched screw, for the purpose of engaging and disengaging the coupling; but for the transmission of a smaller power a common hand lever, as shown in the figure, is quite sufficient.

With regard to friction couplings and their application generally, it may be observed that they have not been so extensively used as is desirable, not only for the prevention of accident, but in many cases where occasionally only a certain portion of the shafting or machinery in an establishment is required to be put in motion. It appears however desirable that in all extensive works and manufactories there should be a friction coupling at the commencement of every main line of shafting. If they were thus applied, it is not improbable that many accidents which now prove fatal might be considerably mitigated if not avoided, by thus having the means at hand of stopping a line of shafting or a room of machinery at a moment's notice, thereby avoiding the too often fatal delay of having to run to the engineer to give notice to stop the engine. Instances have more than once come under the writer's observation, where, had there been the means of instantly stopping the shafting, life might have been saved; and everything which has a tendency to prevent accident is undoubtedly worthy of serious consideration.

An application of this friction coupling may it is thought be made with advantage, especially in heavy driving, in place of the ordinary fast and loose pulley, in which a considerable economy in the wear

and tear of straps or belts might be reasonably expected, as the necessity for traversing the strap backwards and forwards on to the fast and loose pulley would be avoided: in addition to which a further saving would be effected in the strap pulleys themselves, the driving pulley being required only half the width of those at present in use; for the friction coupling or driving pulley answering the double purpose of fast and loose pulley, the latter would not be required. Friction pulleys for this purpose might be made at a comparatively small cost, as they would require only one set of double levers, with their inner ends forked, so as to encircle the shaft and connect with the side links or coupling bars to the forked lever G.

In arranging this friction coupling it has been endeavoured as far as possible to combine powerful and efficient action, simplicity of construction, and an easy and accurate system of adjustment against wear of the friction surfaces, with effectual means of increasing the power transmitted to any limit within the strength of the materials acted upon, together with cheapness and durability of construction.

The CHAIRMAN enquired how many of the friction couplings were at work, and what amount of power was transmitted.

Mr. F. WRIGLEY replied that there was only one at present at work, namely at the Holm Head Works, Carlisle, where it was required as an essential condition that that portion of the works to which the coupling was applied should be driven by means of a friction coupling; and having found difficulty in obtaining one sufficiently simple in its construction, efficient, and inexpensive, he had been led to construct the one now described. The coupling was secured to the back of a 4 feet mitre wheel, and transmitted from 35 to 40 horse power without slipping, whilst it afforded the means of starting and stopping the machinery very gradually.

Mr. B. FOTHERGILL remarked that the use of friction couplings for shafting was a subject that was engaging a great deal of attention at the present time in the manufacturing districts, in consequence of the number of accidents in mills arising from carelessness and rashness in attempting to throw machinery into gear by means of the straps without stopping the shafting. The straps were usually hanging ready on a hook alongside the driving pulleys, and the workpeople were constantly attempting to save themselves time and

trouble by this dangerous practice, although repeatedly warned against it; one would get up to slip the strap on to the driving pulley when it was running full speed, whilst another laid hold of the strap to prevent it from lapping, and although frequently cautioned would persist in keeping hold of the strap after it got into motion, and sometimes became entangled with it and drawn into the machinery. He had known many such accidents occur where the proprietors were blamed for not sufficiently fencing off the straps, though the accidents were really attributable to acting contrary to their orders.

It was essential in many cases of machinery, such as calendering and print works, to be able to start the machines without a shock, and in this respect a friction clutch gave an important advantage over other couplings, by beginning with a slow motion and gradually accelerating the speed until the full rate was obtained, without any liability to a sudden shock. The friction coupling now described possessed an advantage, he thought, in the arrangement of the levers forming the knuckle joints for engaging or disengaging the friction blocks; each pair of levers formed a straight line when the coupling was engaged, the levers being exactly in the line of the force, so that the handle did not require to be firmly secured to prevent the clutch coming out of gear, and had no tendency to fly back, being at rest without any strain upon it when the coupling was in gear. The construction was good for readily increasing the effective length of the levers when wear occurred, by means of the adjusting wedges acting on the bearings at their outer extremities, so as always to get the thrust in the right direction. He remembered that at Messrs. Sharp's works many years since there was a contrivance for disengaging the bevel wheel at the end of a line of shafting by lifting the end of the shaft so as to lift the bevel wheel out of gear with the driving wheel; but this plan was not free from risk of accident, as the lifting lever might come unfastened and allow the wheel to drop down into gear again, risking the breakage of the teeth or a more serious accident.

The Chairman thought in the coupling described in the paper there was a good application of the toggle joint, and the use of such couplings would certainly be advantageous in many cases; the objection to the general adoption of clutches of that kind would of course be their expense.

Mr. E. A. Cowper observed that the only objection to such contrivances was no doubt their expense; friction couplings were certainly most useful in connecting machinery, particularly where a portion had to be started and stopped without requiring the stoppage of the rest of the work. He remembered seeing a form of clutch acting on a similar principle which was constructed by Mr. Oldham at the Bank of England many years ago; the copper plate machinery was all worked at that time by friction couplings, but the machinery was now taken down: there were four segments driven out against a friction ring by four levers placed radially and pushed out by a sliding clutch on the shaft, so that they had in effect the action of a toggle joint; the rubbing surfaces were lined with copper, for the purpose of obtaining a greater amount of friction. In consequence of having four segments, instead of only two, a smaller extent of motion would be required to disengage the clutch, $\frac{1}{32}$ inch motion of the segments being sufficient to clear the face of the friction ring; but with two segments a longer motion would be required to enable the ends of the segments to clear the ring, the segments being nearly semicircles instead of quadrants.

The Chairman asked whether there had been any experience of the amount of wear of the rubbing surfaces in the clutch described in the paper, and whether they were lined with copper or any other material.

Mr. F. Wrigley replied that the coupling now at work had not yet been in use for a sufficient length of time to show any perceptible wear. The rubbing surfaces of both the friction ring and segments were simply cast iron turned, which was found to work satisfactorily and would of course be a less expensive construction.

Mr. A. B. Cochrane asked what was the cost of the friction coupling now described.

Mr. F. Wrigley said the cost for one to transmit 30 to 40 horse power would be about £50 or £60 complete, the coupling being 3 feet 10 inches diameter inside the friction ring.

The Chairman proposed a vote of thanks for the paper, which was passed.

The following Paper, by Mr. Alexander Samuelson, of Hull, was then read:—

ON OIL MILL MACHINERY.

Before considering the comparative advantages of the several appliances now used for the purpose of expressing Oil from seeds or nuts, forming the particular subject of the present paper, it may be interesting to refer briefly to the methods previously adopted before the present high state of perfection in the manufacture of machinery had been arrived at.

The means adopted for extracting oil in the last century by the natives of Ceylon, where cocoa nuts and other seeds abound, were of the most primitive description; the apparatus as illustrated in Fig. 1, Plate 4, consisting simply of a few poles stuck into the ground, supporting two parallel horizontal bars AA, between which was placed a bag B containing the seed or pulp of the cocoa nut, from which the oil was to be expressed; a lever C was then brought to bear against one or both of the horizontal bars for the purpose of bringing them together and thereby causing the required pressure upon the seed. This rude apparatus was one of the most approved oil mills of that period. The pestle and mortar, as shown in Fig. 2, was also used for the same purpose; and from the nature of these appliances the process was necessarily exceedingly slow and inefficient. An improvement upon this apparatus is shown in Fig. 3. It is the invention of Mr. Hebert, whose object was to construct what he considered a powerful and effective machine, combining simplicity and cheapness with economy of labour. It consisted of an upright post A fixed firmly into the ground, the stump of a tree being often used, upon the lower and upper ends of which were projecting pieces, the upper one forming the joint of the long horizontal lever B, and the lower one the joint of the short vertical lever C, at the top of which was fixed a roller bearing against the underside of the horizontal lever B, for the purpose of diminishing the friction when the pressure was exerted upon the seed. The fixed upright post A and the vertical lever C in this instance formed the compressing portion of the machine. The pressure was obtained by the weight

of a man suspended from the end of the horizontal lever B. A double machine was also constructed upon the same principle, as shown in Fig. 4, the pressure being obtained either by weights or by a bucket full of water, which was made self-acting in so far that as soon as the bucket touched the ground a valve was opened and the water escaped, thereby relieving the seed from any further pressure. The advantage of the double machine was that it could be made portable and be moved about at pleasure, one half of the press counterbalancing the other when both sides were in action, whereby it was rendered independent of the ground. Another appliance of a similar description is shown in Fig. 5, the only difference being that in this instance there was only one lever B, and the seed bags instead of being placed vertically were placed horizontally in a box C, upon the loose head of which the action of the lever was brought to bear by the same means of animate or inanimate weights. There is also another press deserving of notice, which is shown in Fig. 6. The pressure is here gained by levers and weights B as in most of the foregoing examples, but with this modification that cams C and wedges D are introduced. There is also a modification of this combined lever and cam machine, as shown in Fig. 7, in a press invented by Mr. John Hall, of Dartford, where the pressure is applied at the end of the levers B by means of the steam cylinder A. This apparatus is double, consisting of two pairs of boxes, the cams being placed opposite to each other, so that the operations of compressing the seed and refilling the bags may be carried on simultaneously.

The lever presses having thus been briefly examined, the more approved and modern presses for extricating oil have now to be considered. These are three in number:—the Dutch or Stamper Press, which was invented in Holland: the Screw Press; and the Hydraulic Press; both of which were invented in this country. Before considering the comparative merits of these three presses, it will be advantageous to refer generally to the course of operations to be performed previous to the compression of the seed, which is the last of five operations that it has to undergo.

The first operation consists in passing the seed through a flat Screen or Shaker, which is kept in a constant state of agitation.

In the second operation the seed is passed through a pair of Crushing Rollers, which have the effect of bruising or crushing it.

A pair of these rollers of the most improved form is shown in Figs. 9 and 10, Plate 5. Fig. 9 is a transverse section and Fig. 10 a plan of the rollers. The two rollers are of unequal diameters, the larger one A being 4 feet diameter and the smaller B 1 foot diameter, the breadth of both being 16 inches, or 14½ inches on the face. The larger roller A makes 56 revolutions per minute, driving the smaller one by friction. The seed is supplied through the hopper C by means of a small roller D, very slightly grooved, which is made to revolve for the purpose of feeding the main rollers, being driven by a strap from the larger roller passing over a pulley outside the hopper; the amount of feed is regulated by the regulating plate and screw E. Underneath the rollers are placed scrapers F, kept in contact with them by weights, for the purpose of scraping off any seed adhering to the surfaces after crushing. These rollers for a long time were made of equal diameters; but it was found that they crushed the seed neither so well nor so expeditiously as they do in their present proportions. After the equal sized rollers were found to be inefficient, that known as the Ipswich Mill was adopted, in which the larger roller was 6 feet diameter and the smaller 1 foot diameter; but experience proved that, when any hard substance got between the rollers, the leverage over the journals was so great that it caused much wear and tear upon those parts. Seed crushers have therefore by degrees adopted the medium sized rollers, which are found to be exceedingly effective and not liable to derangement. A pair of rollers such as are shown in Figs. 9 and 10 will crush upon an average about 4½ tons of seed in 11 hours, which is sufficient for two sets of hydraulic presses.

The third operation consists in grinding the seed under a pair of Edge Stones, as shown in Figs. 13 and 14, Plate 6. Fig. 13 is a vertical section, one of the stones being removed; and Fig. 14 is a plan with one of the stones in section. Fig. 15 shows the vertical driving shaft partly in section. The two edge stones AA are 7 feet 6 inches diameter and 16 inches thick, bevelled to 11½ inches broad on the face, weighing together about 7 tons; the vertical driving shaft B makes about 17 revolutions per minute. The seed is kept under the stones by means of the sweeper D, and at the proper period is collected and swept off by a second sweeper E, the slide or cover F being withdrawn for its discharge; while the grinding is being

performed, the sweeper E is raised from the bed plate C by the hand lever G, as shown by the dotted line. The edge stones, if of good quality and the seed not impure, require to be refaced about every 3 years, and will last from 15 to 20 years according to their quality. One pair of edge stones will grind sufficient seed for two double hydraulic presses ; the process of grinding lasts for about 25 minutes, previous to the seed being transferred to the next operation.

The fourth operation consists in heating the ground seed in the Heating Kettle shown in Figs. 11 and 12, Plate 5. Fig. 11 is a vertical section of the heating kettle, and Fig. 12 a plan. The kettle is heated by steam, and consists of two cylindrical chambers A and B, one above the other, each of which is composed of an external casting C and an internal casting or inside kettle D, with a sufficient space left between the two castings round the sides and at the bottom to allow a free circulation of the steam. The steam is admitted by the pipe E, and the condensed water passes off at F from the bottom of the kettle. The shaft G gives motion to two arms or stirrers HH in each chamber, revolving at the rate of 36 revolutions per minute, which keep the seed constantly agitated so that every particle of it may come in contact with the heated sides and bottom of the kettle. The upper chamber A is covered with a sheet iron lid I through which the kettle is charged. In heating the seed the upper chamber A is filled first, and the seed is allowed to remain in it from 10 to 15 minutes; the slide J is then withdrawn and the seed falls through the opening K into the lower chamber B, where it remains until it is required to be taken to the press; the door L is then opened and the whole of the seed is discharged from the chamber B by the action of the revolving stirrers H. The seed falls through a funnel M, under which is placed a bag of suitable dimensions to contain a sufficient quantity of seed to make a cake weighing 8 lbs. after the oil is expressed from it. Each of the chambers in the heating kettle will contain sufficient seed for charging one single press ; the heating of the seed is therefore a continuous operation of first charging the upper chamber A, and then allowing the seed to pass into the lower one B, in which it is heated to 170° Fahr., and is then withdrawn and placed in the bags.

Another description of kettle, of a much simpler though less effective kind, is shown in Fig. 8, Plate 4. In this case the seed is

heated on a hot hearth A, being confined within a loose ring B; a spindle with two arms upon it revolves inside the ring, keeping the seed stirred while it is being heated. When the seed has become sufficiently heated, the spindle and stirrers are raised a sufficient height above the top of the ring by the handle D; and the ring being loose on the hearth, the seed is drawn forward by it and scraped into the bag E. In this instance the seed is exposed to the atmosphere, and there is therefore a large amount of heat wasted. It is also liable to become overheated and spoiled, and upon the whole this is a more troublesome operation, as each ring holds only sufficient seed for one bag.

The bags after being filled are placed separately between what are called the hairs, which are bags made of horsehair with an external covering of leather. The same description of bags and hairs are used, whether the oil be expressed by means of the stamper, screw, or hydraulic press.

The final operation of expressing the oil is effected in the Screw Press as shown in Fig. 16, Plate 7, by means of an ordinary square threaded screw A, by which the bag of seed is compressed between the bottom of the box B and the moveable plate C. The power is applied by means of a loose lever inserted between studs fixed in the plates D, which are attached to the screw. The press may be made in a vertical form, and may also be made to lie horizontally, and to be worked either by hand or by power. A very large amount of pressure may be obtained by one of these presses, but the wear and tear and derangement are excessive, and there are few screw presses in existence at the present day giving a correct idea of the exact proportions or pressure applied.

The Stamper Press is shown in Fig. 17, Plate 7. It consists of a long rectangular cast iron box A, open at the top, at each end of which there are two plates between which one bag of seed B is placed, yielding a cake weighing 9 lbs.; next to one of the inner plates is placed a filling up piece, then an inverted wedge C, then another filling up piece, after which is introduced the vertical driving wedge D, and lastly another filling up piece is inserted between the driving wedge and the other inner plate. As soon as the bags B have been placed vertically in the press box in the usual manner, a stamper E made of wood, about 16 feet long and 8 inches

square with a fall of about 22 inches in the final stroke, is allowed to fall at the rate of 15 strokes per minute for a period of about 6 minutes upon the head of the driving wedge D, which is sufficient to drive it down level with the top of the press box A, the stamper being worked by two cams or wypers on the revolving shaft F. Side by side with the stamper E is a second stamper G, immediately above the inverted wedge C, which is held suspended at a fixed point by means of the lever H while the first stamper E is in action; but as soon as it is time to remove the bags, the stamper E is raised by means of the lever H above the point at which the cams come into contact with it, and by the same means the other stamper G which was previously suspended is allowed to fall upon the inverted wedge C, driving it downwards and thereby releasing the working wedge D, so that the attendant may remove the bags and repeat the operation. A press like this will not do more than about 12 cwt. of cake per day.

The last mode of expressing the oil is by means of the Hydraulic Press, which may fairly be said to be the most approved system that has yet been adopted. This press is simply Bramah's press arranged specially for the purpose of expressing oil, and appears to have been in use for this work more or less for 30 years, although the earlier presses were very defective as compared with those in use at the present time. One of the first hydraulic presses that was constructed is shown in Fig. 18, Plate 7. In this arrangement only one press and one set of small pumps was introduced. The box A which receives the seed is in one piece, and runs upon a small tramway for the purpose of withdrawing it from the press to remove the cake and replenish the bags; each time therefore that the press is put into operation the entire box has to be withdrawn in order to empty and replenish it; and it has then to be replaced upon the ram B, after which it is lifted bodily upwards so as to bring it into contact with the press head C, which fits accurately in the press box A and acts as the point of resistance when the pressure is upon the ram. The constant withdrawal and lifting of this heavy box must evidently be a great loss of power and time. Presses of this description have been at work at Deptford until within the last few weeks, but they have now been removed and replaced by those known as Blundell's presses, which are now universally admitted to be the most efficient appliance for the purpose.

Blundell's Double Hydraulic Press is shown in Fig. 19, Plate 7, and in detail in Figs. 20, 21, and 22, Plate 8. Fig. 20 shows a vertical section of the press with an elevation of the pumps; Fig. 21 is a sectional plan of the press with a plan of the pumps; and Fig. 22 is a longitudinal section through the press boxes. The double hydraulic press consists of two distinct presses A and B, Fig. 19, supplied by two pumps C and D, one of which C is 2½ inches diameter and the other D 1 inch diameter, both connected to each distinct press cylinder by means of hydraulic tubing E. The stroke of each pump is 5 inches, and they make 36 strokes per minute; the larger pump C is weighted to 740 lbs. per square inch pressure, and the smaller D to 5540 lbs. per square inch. The diameter of the press rams F, Fig. 20, is 12 inches and the stroke 10 inches. Each press is fitted with four boxes GG, and receives four bags of seed in the spaces HH, producing in all a weight of 64 lbs. of cake at each operation. After the heated seed has been removed from the heating kettle and placed in the canvas and hair bags, which is done as speedily as possible so that it may retain its heat, the attendant first fills one press A, and opens the communication between the large pump C and the charged press A by means of the valves I, which causes the ram to rise until there is a total pressure of about 40 tons exerted on the press; the safety valve connected with the large pump C then rises and is kept open by means of a small spring catch. Whilst this operation is going on in the first press A, the second press B is being filled in the same manner; the communication is then opened between the large pump C and the press B by means of the valves I, the safety valve of the pump C having been replaced in its original position; the ram of the second press B is then raised to a corresponding position with that of the first press A, when the safety valve of the pump C rises a second time. The communication between the large pump C and the press B is then closed, and at the same time a communication is opened by the valves I between the small pump D and the presses; and the extreme pressure exerted by the small pump D, amounting to about 300 tons, is allowed to remain upon the rams for about 7 minutes from the time that they were first brought into action; this together with 3 minutes allowed for emptying and charging the

press is the full time required for expressing the oil in the most effectual manner. The oil in leaving the seed passes through the canvas bag, and then through the hair bag, where it finds a free exit at the edges; thence it runs into a channel or groove K which passes round the upper portion of each press box G; a communication is made from one box to another by means of piping L, so that the oil passes from the upper boxes through the lower ones, and thence into the cistern, which is called the spell tank, being just large enough to hold the produce of one day's work. These presses are not worked with water; it has been found that oil which is not of a glutinous description works much better, and keeps both the pumps and presses in a better condition. It is scarcely possible, if the presses are properly constructed, that they should meet with any accident; this can only occur where through carelessness an excessive weight is placed upon the safety valve levers, or where the valves themselves are allowed to stick through want of cleanliness, from the attendant not taking care to remove the oil which sometimes becomes clotted round the valves. Each of these presses is capable of producing 36 cwt. of cake per day of 11 hours, and the yield of oil may be taken at about 14 cwt. in the same time; this of course depends much upon the nature of the seed. The cake is trimmed or pared at the edges by means of a small paring knife, after which it is put into a kind of rack to allow it to cool and dry, so that it will not become mouldy when stacked. The oil is pumped from the spell tanks into larger tanks, capable of holding from 25 to 100 tons, where it is allowed to remain for some time for the purpose of settling, previous to being brought to the market in that condition, or to undergoing various other processes such as refining.

The question has now to be considered of the relative merits of the three descriptions of presses of the most recent date.

For all practical purposes the screw press is quite unfit to be compared with either the stamper or the hydraulic press, from the objection that it is constantly liable to break-downs when driven by steam power, there being no portion of the machinery that will yield if the pressure is not relieved in time either by the attendant or by some self-acting contrivance, the best of which are very uncertain in their action; whereas in the case of the stamper press,

the stamper being loose and independent of the press box, any risk of breakage by an overstrain or excess of pressure is in a great measure avoided by the stamper recoiling and leaving the wedge at a fixed point after it is tightly driven home. It might be thought that, since a greater pressure can certainly be obtained by the screw than by the stamper press towards the latter portion of the operation, and from the fact of there being nothing which will yield except the seed, the screw press must consequently express the oil more speedily and effectually: but this is not the case, for the stamper is made of sufficient weight to enable it to extract all the oil, although at a slower rate; and the regularity in its working, owing to its freedom from break-downs, enables it to crush on an average quite as much if not more seed in a given time than the screw press. If the loss of profit during repairs and the cost of the repairs themselves be taken into consideration, there can be no doubt that the stamper press is far superior to the screw, notwithstanding that the former seems at first but a primitive appliance as compared with the latter. In this particular of freedom from break-downs, however, the hydraulic press is far superior to either of the other two; for the safety valves of the pumps rise at the precise moment when the requisite force is obtained; and the force can be increased far beyond that which can be obtained by either the screw or stamper. Independently however of this latter advantage, the hydraulic press combines in itself the good qualities of both the other presses, without their accompanying disadvantages. For in the hydraulic press there is a certain accumulation of force which is maintained for a sufficient length of time without any possibility of injury occurring to the machinery: whereas, as has already been observed, the accumulation of force in the screw is liable to be increased beyond a safe point, leading to the destruction of the apparatus; and in the stamper the very safeguard which it possesses in its tendency to recoil leads to a loss of time whilst it is performing its duty. Taking into consideration therefore the freedom from derangement of the hydraulic press as compared with the screw, and its continuous action without loss of time or power as compared with the stamper, it certainly ranks higher than either as a mechanical appliance for the required purpose. The wear and tear in the working parts of the screw as compared with that in the other presses has been quite

sufficient to drive it from the field, and to leave the only practical question between the stamper and the hydraulic press. In corroboration of this point, independently of the fact that the screw is almost entirely abandoned in this country, it was clearly proved to be inferior to the other two, by a series of careful experiments made some years ago at considerable expense at the Chateau d'Eu, where an oil mill was erected by the late French King, Louis Philippe, and worked by the three different methods under consideration. This mill came under the writer's personal inspection about two years ago, when he had occasion to visit it with Mr. Graham of London, a practical seed crusher, for whom he has since erected the machinery in a mill near London, which is represented by the model now exhibited. The hydraulic press in the French mill was an inferior piece of workmanship: had it been similar to those used in England the comparison would have been even more unfavourable to the screw press.

Next as to the merits of the stamper as compared with the hydraulic press, the experience of the practical crushers in this country will give the most correct guide; and the writer has ascertained from Mr. Blundell, of Messrs. Blundell Spence and Co. of Hull, to whom the present state of perfection of oil mills is so greatly owing, that the cost of labour with the hydraulic press is 7*d.* per quarter of seed crushed, whereas with the stamper it is 8*d.* for the same amount of work done, being a saving of about 12½ per cent. with the hydraulic press. Moreover the wear and tear in the stamper mill, not only in the machinery itself but also in the building, is twice as great as in the hydraulic mill, owing to the incessant shocks caused by the falling stamper, which are transmitted to the building and its foundation; there is also a constant destruction of wedges going on, which is altogether avoided in the hydraulic press, although against this there is in the hydraulic press the expense of the rams and pump packings. And thirdly, as a practical proof, which is after all the best, we find that the mills in Hull which were originally worked by stampers are now completely remodelled; and there are 94 hydraulic presses in use and only 15 stampers, the latter being equivalent in their productive powers to only about 5 hydraulic presses; the stampers consequently now form only about 5 per cent. of the machinery in use there. The writer

can also state that Messrs. Earles and Carter of Liverpool, the most extensive seed crushers in the country, had nothing but stampers in use in 1851, at which period one double hydraulic press was fixed by his firm in their establishment. This was tested very severely against the stamper, and met with unfair usage for a period of six months; for the men soon finding that such a press would produce more than twice as much as the stamper, feared that, unless the advantages of the hydraulic press enabled the employer to increase his manufacture, it would throw out of employment one half the number of press hands then employed. Like most uneducated men however they omitted to take into consideration that the facility of production would necessarily increase the sale of the article manufactured, and that if they were thrown out of one branch they would find employment in another.

The following are the comparative results of the stampers and the hydraulic presses in the above works, the area of floor upon which the machinery stands being the same in both cases, 121 feet by 30 feet. With the 12 stampers previously employed the largest quantity crushed in one year, day work only, was 13,000 quarters of seed: but with 8 hydraulic presses working day and night they have worked 52,000 quarters, which would be equivalent to about 30,000 quarters for day work only; and with 10 hydraulic presses, which now form their complement, they will crush 65,000 quarters of seed working day and night. Then with the stampers they were compelled to work the seed twice over, whereas with the hydraulic presses it is only necessary to work it once, in both instances yielding the same quantity of oil; and the consequent saving of labour is equivalent to from 20 to 25 per cent. The difference in point of wear and tear between the two modes of crushing is found to be considerably in favour of the hydraulic presses, while the cost of wedges with the stampers was very considerable, and altogether there is an important saving in the new method. As to the comparative amount of power required, there is found to be a large saving in favour of the hydraulic presses.

The practical conclusions from the results of working appear then to be, that in the same sized mill the hydraulic presses produce about three times as much oil as the stampers: that they do this with less wear and tear: and at a considerable saving of labour, since the seed

has only to be handled once: and that the general expenses in working the hydraulic mill as compared with the stamper, owing to the increased production, are much less per quarter of seed crushed; for the consumption of coal, general charges, and interest on plant, &c., will be the same whether 13,000 quarters per annum are crushed by the stampers or three times that quantity by the hydraulic presses.

In conclusion it may be interesting to give some particulars as to the extent of this manufacture. It appears from the official returns that the quantity of seed imported into this country for the oil manufacture was 364,000 quarters in 1841, increasing in 10 years to 630,000 quarters in 1851, and amounting in 1856 to about 1,100,000 quarters; the last amount producing about 144,000 tons weight of cake, and 56,000 tons of oil.

The cake is used for feeding cattle; and the oil is used chiefly for painting, and a very large portion is again exported. The immense increase however in the quantity of cake produced shows either that there are more cattle fed upon it in this country than there were a few years ago, or that a much larger quantity of cake is consumed per head of cattle than used to be. It is difficult to ascertain correctly in which respect the greatest increase has taken place, but the increased consumption of cake may probably be attributed rather to the more general adoption of feeding cattle on linseed cake.

It appears that to crush the seed imported in 1856 there were required about 150 to 160 double hydraulic presses at work day and night; nearly 100 of these are at work in Hull, and the rest are distributed all over the country, the more important mills being in London, Liverpool, Grimsby, &c.

It is on account of the prominent position that the town in which the writer resides holds in the manufacture described in this paper, that he has offered these particulars, responding to the call of the Council for a paper on this subject amongst the list of subjects for papers; and he will be happy to afford any further information to the Institution that may be desired.

Mr. A. Samuelson exhibited specimens of the seed from the several processes described in the paper, and a model of the large oil mill at the Isle of Dogs, that had been referred to, which consisted of three complete compartments, each containing two double hydraulic

presses with a pair of edge stones and rollers, all driven by steam power, the several portions of the mill being connected by friction couplings. He remarked that one other point to be noticed, in reference to the superiority of the hydraulic press and stamper as compared with the screw press, was that it was found by seed crushers that a slight rebound of the press after each increase of the pressure applied was advantageous, allowing the oil expressed from the seed to escape more readily: the stamper recoiled after each blow and was liked on that account, and in fact the ram of the hydraulic press also accomplished the same object by recoiling slightly between each stroke of the pump, the pump being single-acting; but with the screw press there was no part of the apparatus that could give way in this manner. A great point in oil manufacture consisted in bruising the seed well between the rollers before applying the pressure in the final process, and there was more importance in that than in any other operation, as the oil was thereby expressed much more freely and thoroughly.

Mr. B. Fothergill asked whether the rollers were covered with any hard and durable material.

Mr. A. Samuelson replied that the rollers were not covered, but merely hard cast iron, which was found sufficiently durable for the work. A beneficial effect as regarded the working of the rollers was also found, owing to a small amount of slip arising with rollers of unequal diameters: the smaller roller lagging behind a little, being driven only by friction through the medium of the intervening seed, gave a slight cutting or grinding action, which greatly increased their efficiency in crushing the seed, and experience had resulted in the adoption of rollers of 4 feet and 1 foot diameter as shown in the drawing.

The Chairman enquired how often the rollers required to be turned up to ensure a sufficiently even face for crushing the seed in the most effectual manner.

Mr. A. Samuelson said the durability of the rollers varied with the quantity of the seed to be crushed and the hardness of the metal; they worked for 12 or 18 months generally without requiring to be turned up, but sometimes for only 2 or 3 months. They were made of cast iron about as hard as could be conveniently turned, though probably not quite so hard as the plate rolls used in iron works.

Mr. J. E. McConnell asked what was the speed at which the surface of the rollers worked.

Mr. A. Samuelson replied that the large roller, 4 feet diameter, was driven at about 56 revolutions per minute, giving a speed at the circumference of the two rollers of about 700 feet per minute.

Mr. B. Fothergill considered the paper that had been read was a very valuable one, and of great practical interest; it was a kind of paper particularly serviceable to the Institution, giving the practical results obtained from long experience, and they were much indebted to Mr. Samuelson for the great trouble and care he had bestowed upon its preparation. It brought forward clearly in one view the whole history of the process of seed crushing, showing what had been the early plans with the successive improvements that had been effected up to the introduction of the modern machinery used in oil mills. Some of the primitive contrivances for expressing the oil evinced considerable ingenuity and mechanical skill on the part of the early inventors, although without any previous example to guide them. It was particularly interesting to see to what an extent economy of time and labour had been kept in view, as in the case of the early press that had been noticed as invented by Mr. Hebert, which was certainly very simple in construction and action, and had an advantage in saving of labour and of unnecessary dead weights, the workman himself acting as the weight for expressing the oil by raising himself into the scale suspended from the end of the horizontal lever, as soon as he had placed the seed bags in the press, and thus no time was lost in the process. One name was pointed out for special notice by the history of the contrivances adopted for expressing the oil, namely that of Bramah, who appeared both to have the merit of the first contrivance for screw propulsion now coming into such universal use, and also by the invention of the hydraulic press to have superseded all other appliances for expressing oil, and supplied the most important, powerful, and universally applicable means that existed for applying great pressure.

Mr. Sampson Lloyd asked whether any adaptation of the hydraulic press had been attempted for expressing oil from other seeds, as well as linseed.

Mr. A. Samuelson said the hydraulic press was applicable for all seeds, and also for nuts containing oil, such as the cocoa nut; but in some few seeds, such as rape seed, a preliminary process called

"clodding" was found necessary, in which the seed was made into a sort of pulp in extracting the first portion of the oil; in expressing the oil from rape seed many seed crushers reserved one of the old stampers for clodding the seed before submitting it to the final pressing by the hydraulic press, the seed being thus worked twice over so as to express the oil more thoroughly.

Mr. P. D. Bennett observed that a similar principle was applied to malt crushing and splitting beans.

Mr. R. Williams asked whether the hydraulic presses were always placed vertically, as there appeared to be some disadvantage in that arrangement from the greater height of lift to the upper portion of the work.

Mr. A. Samuelson replied that the presses were always placed vertical in this country, and the question of their arrangement had been very closely gone into in America, where horizontal presses had been tried for the purpose of placing the bags in more quickly and easily; but it was found that the oil could not be collected so well as in the vertical presses with vertical piping, and the hair bags were subjected to wear at the bottom as they had to slide horizontally along the bottom of the press. The only advantage in the horizontal presses was that all the bags were reached at the same level; but this was not a point of much importance, as they could easily be lifted up in the vertical presses and there was only a moderate height to reach. A press had been designed by Mr. Bodmer, provided with a quadrant by which it could be laid down for placing the bags in it and raised up again for compressing the seed; but it was evident that such a plan would involve a great loss of power and time in raising and lowering the press, and the vertical press described in the paper was the one that had proved most practically successful.

Mr. E. A. Cowper asked whether any plan had been tried for keeping the seed hot whilst in the presses, by placing it in hollow boxes heated by steam, which had been attempted in some French presses for other purposes.

Mr. A. Samuelson said that plan had been employed in making stearine and in other manufactures, where it was important to keep up the temperature in order to preserve fluidity, but he believed it had not been tried in oil mills; it might be effected with no difference except the use of hollow boxes and flexible steam pipes,

but he thought the additional heat was not of so much importance in expressing oil as to be worth the additional complication.

Mr. E. A. Cowper enquired whether the edge stones used for grinding the seed were shod with iron to make them more durable.

Mr. A. Samuelson replied that the edge stones were not shod, but were made of Derbyshire stone which was very hard and worked well without much wear; Aberdeen granite had been previously tried, but was found to get smooth and slip after working for a short time.

The Chairman asked what increased durability there was found to be in the hydraulic presses by working them with oil instead of water.

Mr. A. Samuelson said the cupped leathers for packing the rams lasted longer when the presses were worked with oil, and there was no perceptible wear of the rams; but with water they were liable to cut, in consequence of small particles of grit being carried in with the water, and some corrosion of the iron taking place.

Mr. E. A. Cowper asked how the safety valves of the hydraulic presses were arranged so as to blow off always at exactly the fixed pressure; there was sometimes a difficulty in this when the area of the valve was very small and the pressure great, and he had known of an instance in which the press had been burst in consequence of the valve being so well ground into its seat as to fit tight at the lower edge, which materially increased the load per square inch on a valve of so small an area. He had adopted a plan for meeting the difficulty by making the seating of the valve truly conical, but giving the valve itself a slightly rounded or curved face, so that the effective area of pressure was kept constant, the valve being in contact with the seating only at one part.

Mr. A. Samuelson said the safety valves used in oil presses were conical brass valves, about 1 inch or $1\frac{1}{4}$ inch long, about $\frac{3}{16}$ inch diameter and about $\frac{3}{16}$ inch diameter in the seat, tapered so as to leave very little margin for irregularity of pressure. There was generally however very little action of the safety valves, as the workmen soon got to know when the oil was completely expressed.

The Chairman proposed a vote of thanks to Mr. Samuelson for his paper, which was passed.

Mr. J. E. McConnell said that this being the last meeting during Mr. Whitworth's present term of office as President of the Institution,

he begged to express the gratitude they felt for the very kind and able manner in which he had presided at so many of the meetings, and the valuable and efficient support he had given to the Institution. Mr. Whitworth's name would remain inseparably associated with the mechanical engineering of this country, and receive the respect and esteem of mechanics, from the wide field of improvement he had opened in mechanism and the great advance he had effected by his measuring apparatus and the system of screw threads that he had introduced. His term of office had also been marked by the further important step of introducing the decimal system of measurement, which he had brought forward in connexion with the Institution, and which there was no doubt would lead to great advantages in all mechanical works as well as in a more extended field. He moved that the cordial thanks of the Members be presented to Mr. Whitworth, which was passed unanimously.

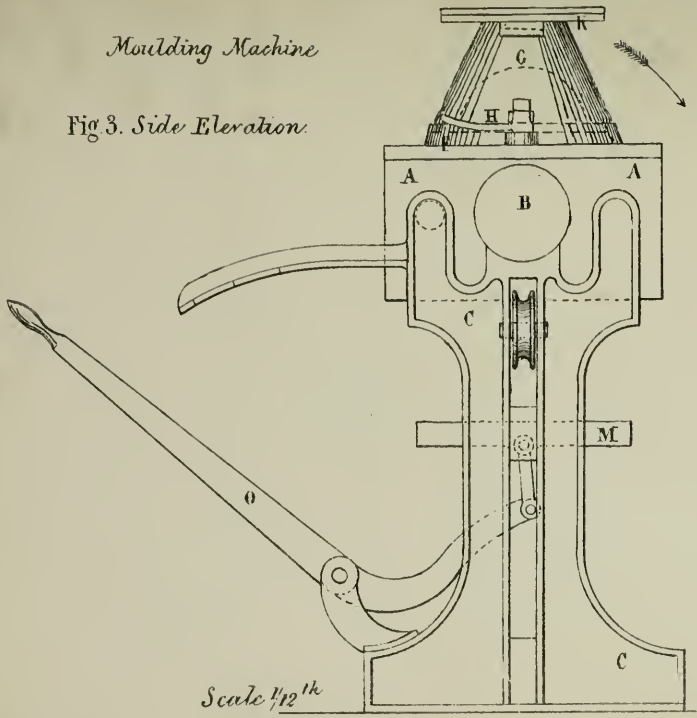
The Chairman said it was very gratifying to him to know that what he had done during his presidency had met with the approbation of the Members, and it gave him great pleasure and satisfaction to have been of service to the Institution.

The meeting then terminated. In the evening a number of the Members dined together at the Hen and Chickens Hotel, in celebration of the Eleventh Anniversary of the Institution.

Plate 2.

Moulding Machine

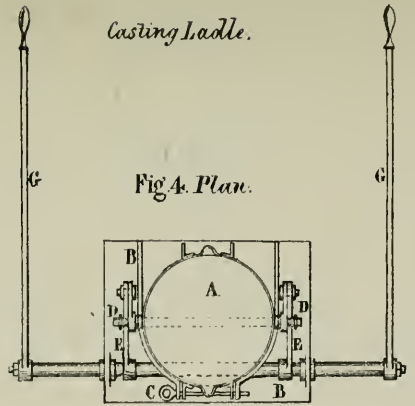
Fig 3. Side Elevation.



Scale 1/12th

(Proceedings Inst M. E. 1858. Page 14)

Casting Ladle.



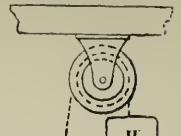
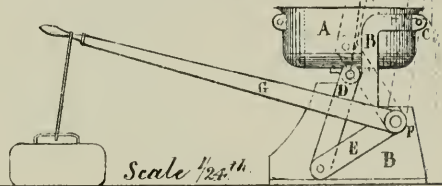


Fig 5. Side Elevation.



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Ins. 12 6 0 1 2 3 4 5 Feet

FRICTION COUPLING.

Plate 3.

Fig 1. *Front Elevation.*

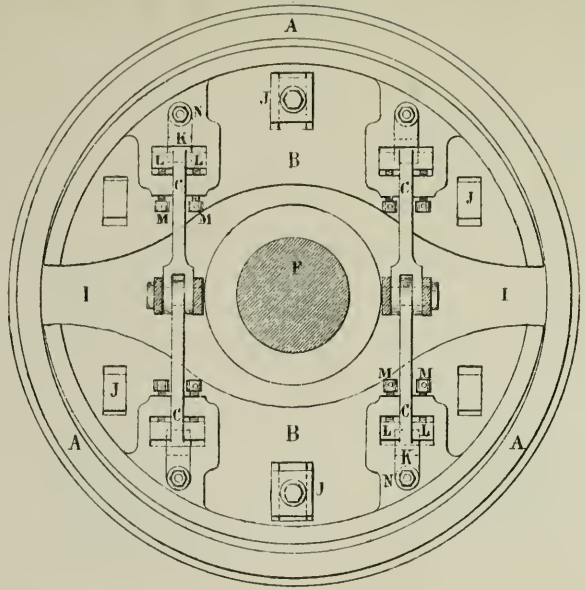
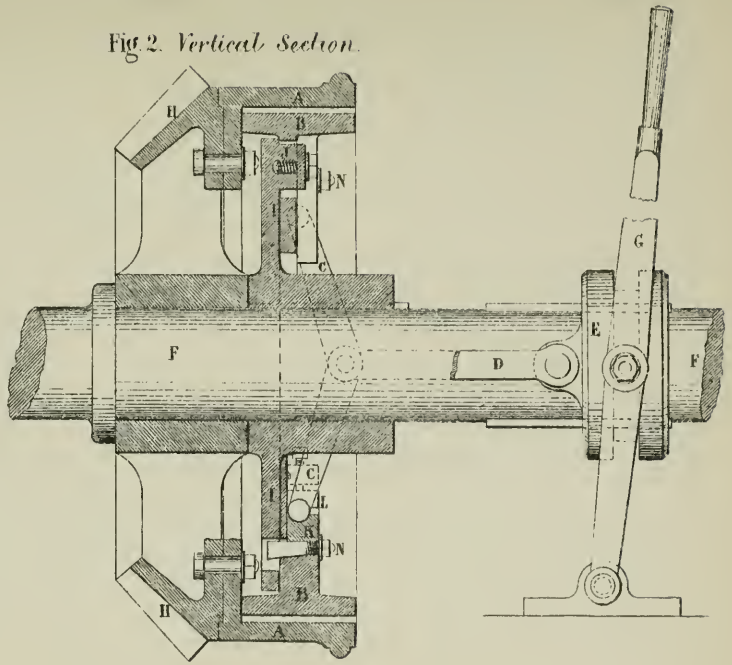


Fig 2. *Vertical Section.*



Scale 1/12th Ins. 12 9 6 3 0 1 2 3 Feet

(Proceedings Inst. M.E. 1858 Page 22.)

Early Appliances for expressing Oil.

Fig. 1. *Primitive Oil Press.*

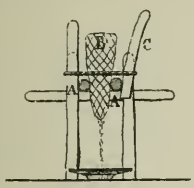


Fig. 2. *Pestle and Mortar Press.*

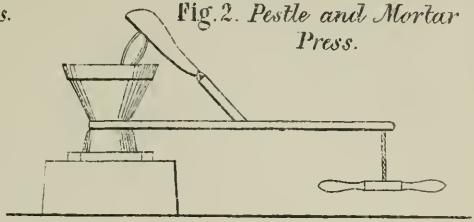


Fig. 3. *Single Lever Press.*

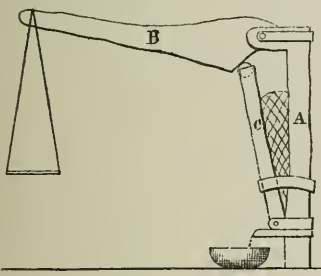


Fig. 4. *Double Lever Press.*

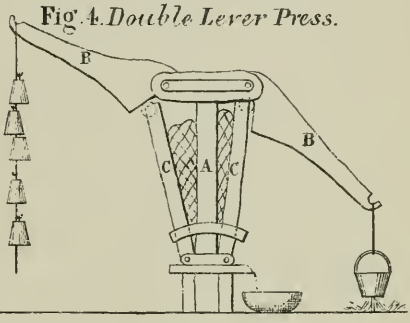


Fig. 5. *Horizontal Lever Press.*

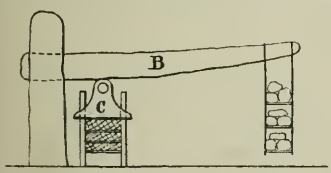


Fig. 6. *Lever and Cam Press.*

Fig. 8. *Early Heating Kettle.*

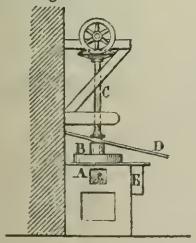
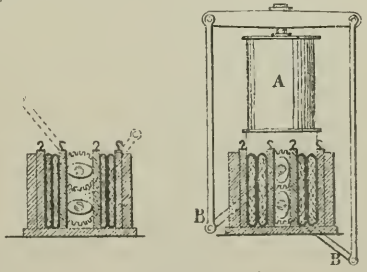


Fig. 7. *Double Steam Cam Press.*



(Proceedings Inst. M.E 1858. Page 27)

Scale 1/100.th

OIL MILL MACHINERY.

Plate 5.

Crushing Rollers and Heating Kettle.

Fig 9. *Transverse Section of Crushing Rollers.*

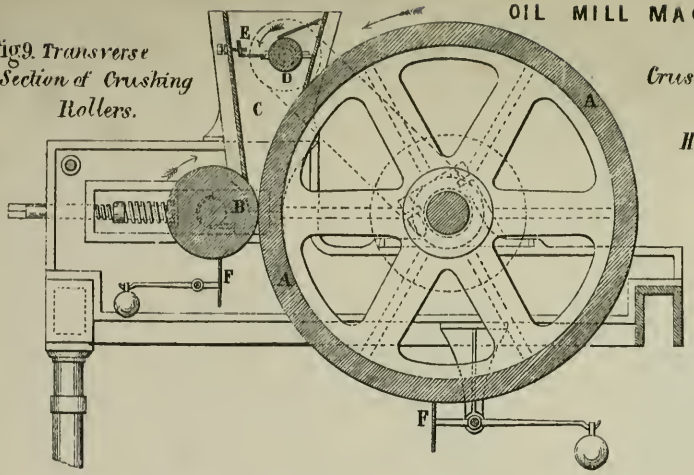
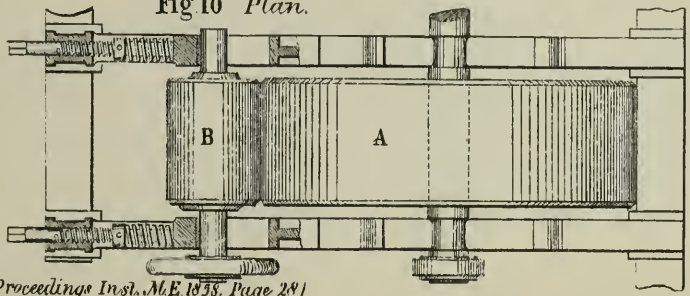


Fig 10 *Plan.*



(Proceedings Inst. M.E. 1858. Page 28)

Fig 11. *Vertical Section of Heating Kettle.*

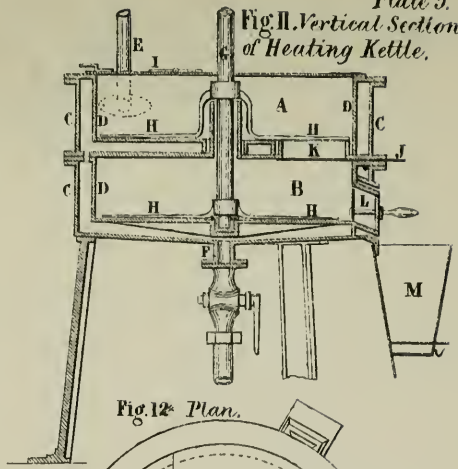
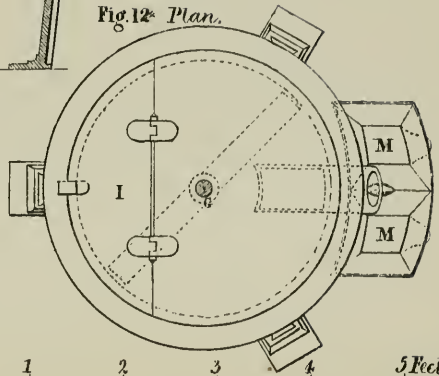
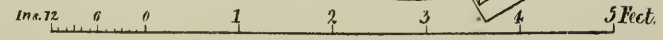


Fig 12. *Plan.*



Scale 1/24th



Edge Stones.

Fig. 15.
Vertical Shaft.

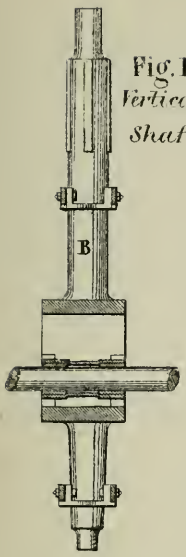


Fig. 13.
Vertical Section

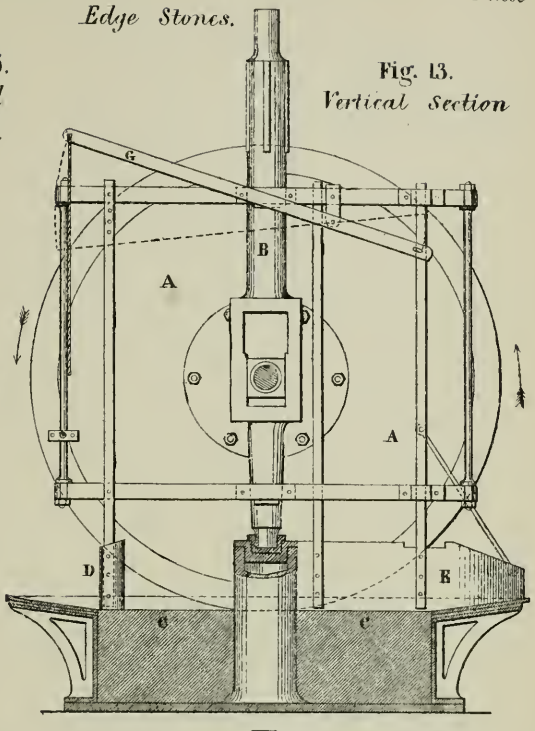
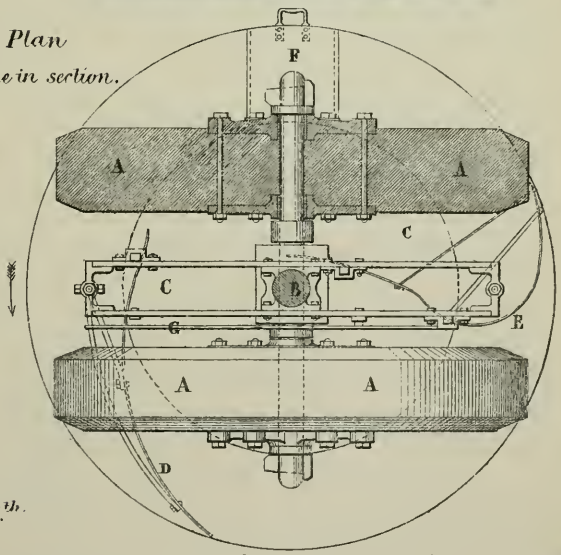


Fig 14. *Plan with one Stone in section.*



Scale 1/36th.

Ins 12 6 0 1 2 3 4 5 6 7 8 9 10 Feet.

(*Proceedings Inst. M.E. 1858. Page 29.*)

Modern Appliances for expressing Oil.

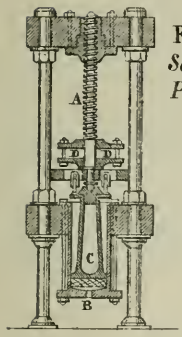


Fig. 16. *Screw Press.*

Fig 17. *Stamper Press.*

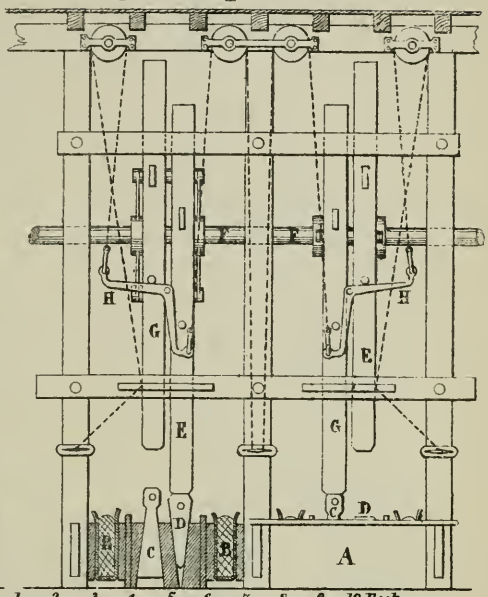


Fig. 18. *Early Hydraulic Press.*

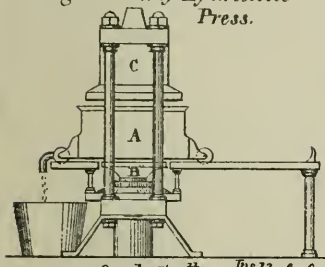
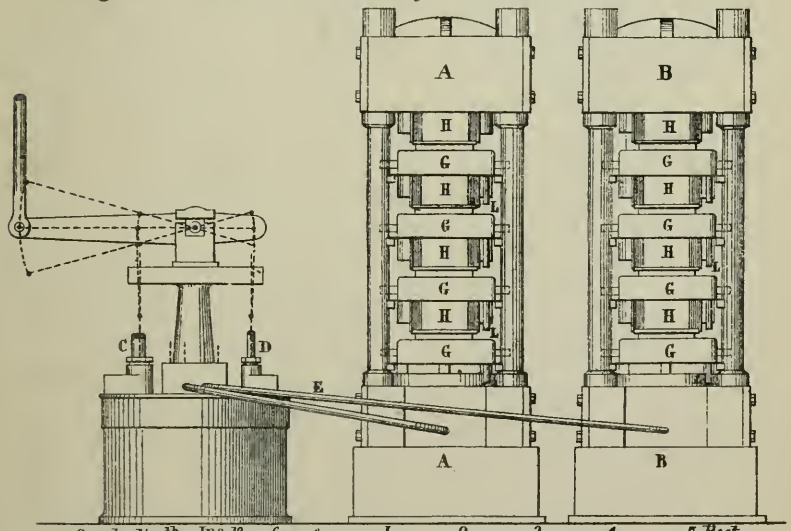


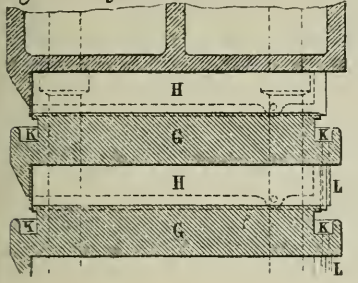
Fig. 19. *Present Double Hydraulic Press.*



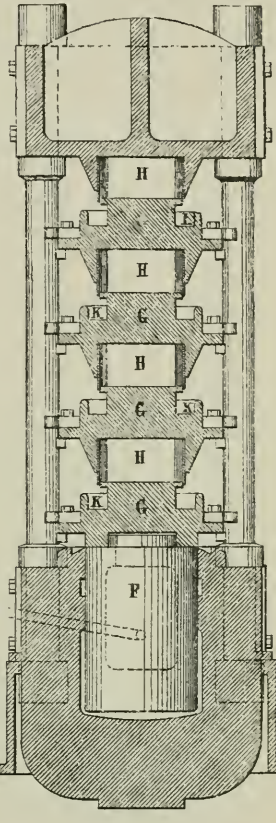
(Proceedings Inst. M.E. 1858 Page 31.)

Hydraulic Presses.

Fig. 22 *Longitudinal Section of Press.*

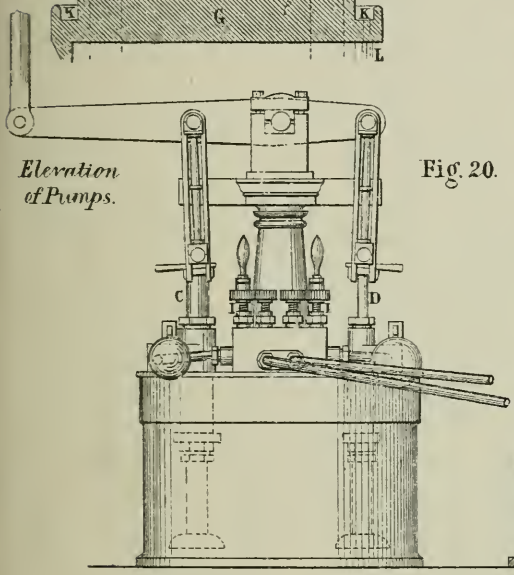


Vertical Section of Press.



Elevation of Pumps.

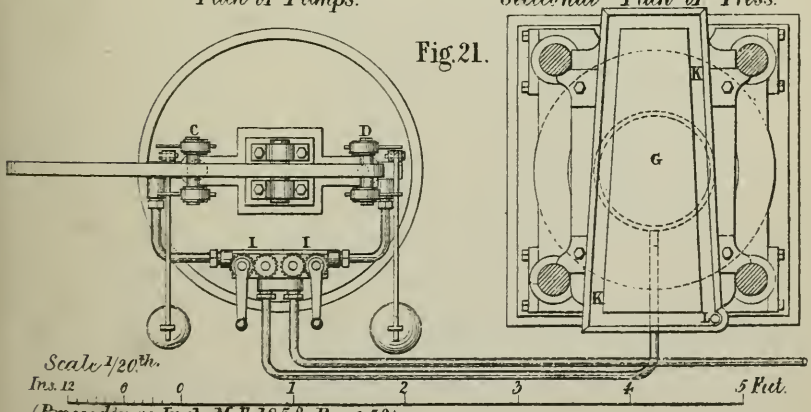
Fig. 20.



Plan of Pumps.

Sectional Plan of Press.

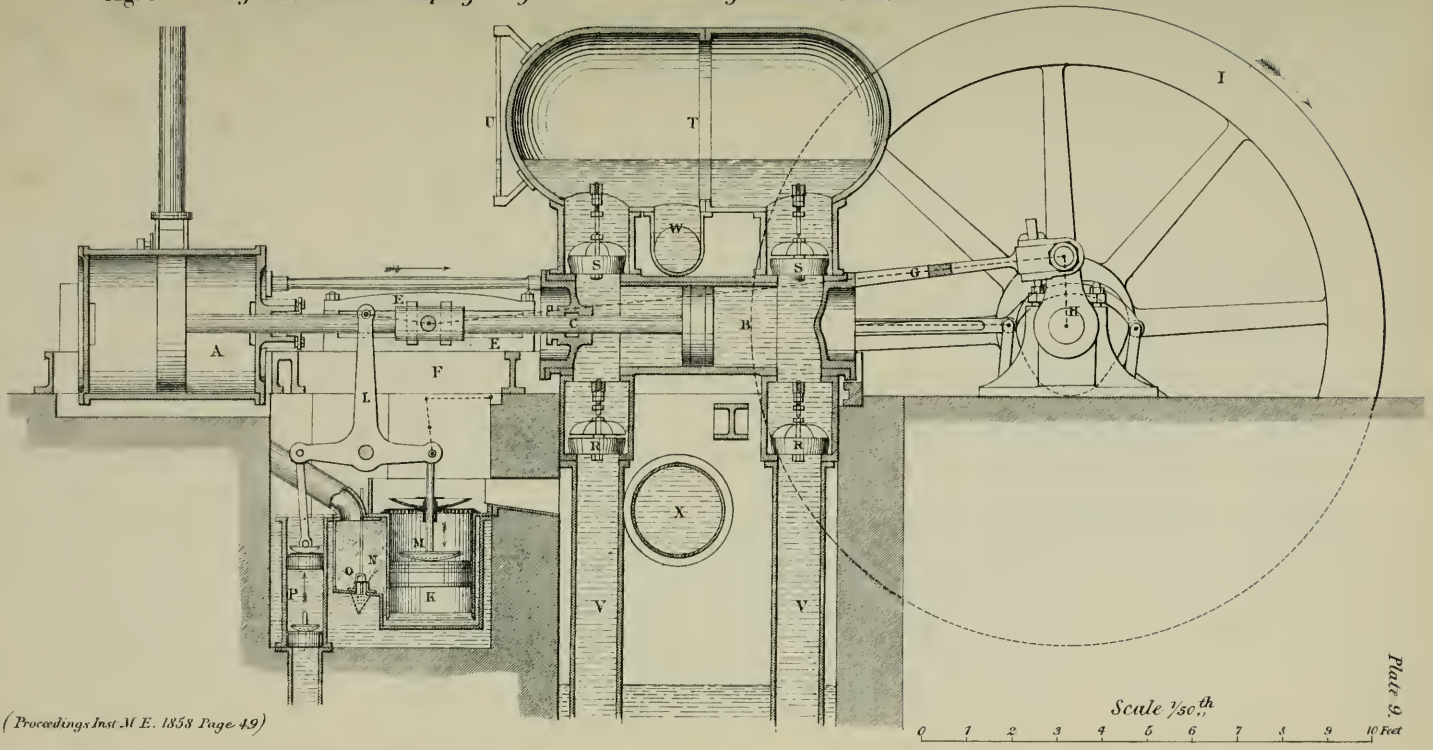
Fig. 21.



(Proceedings Inst. M.E. 1858. Page 32)

HORIZONTAL PUMPING ENGINES.

Fig. 1. *Crystal Palace Pumping Engines* *Longitudinal Section*



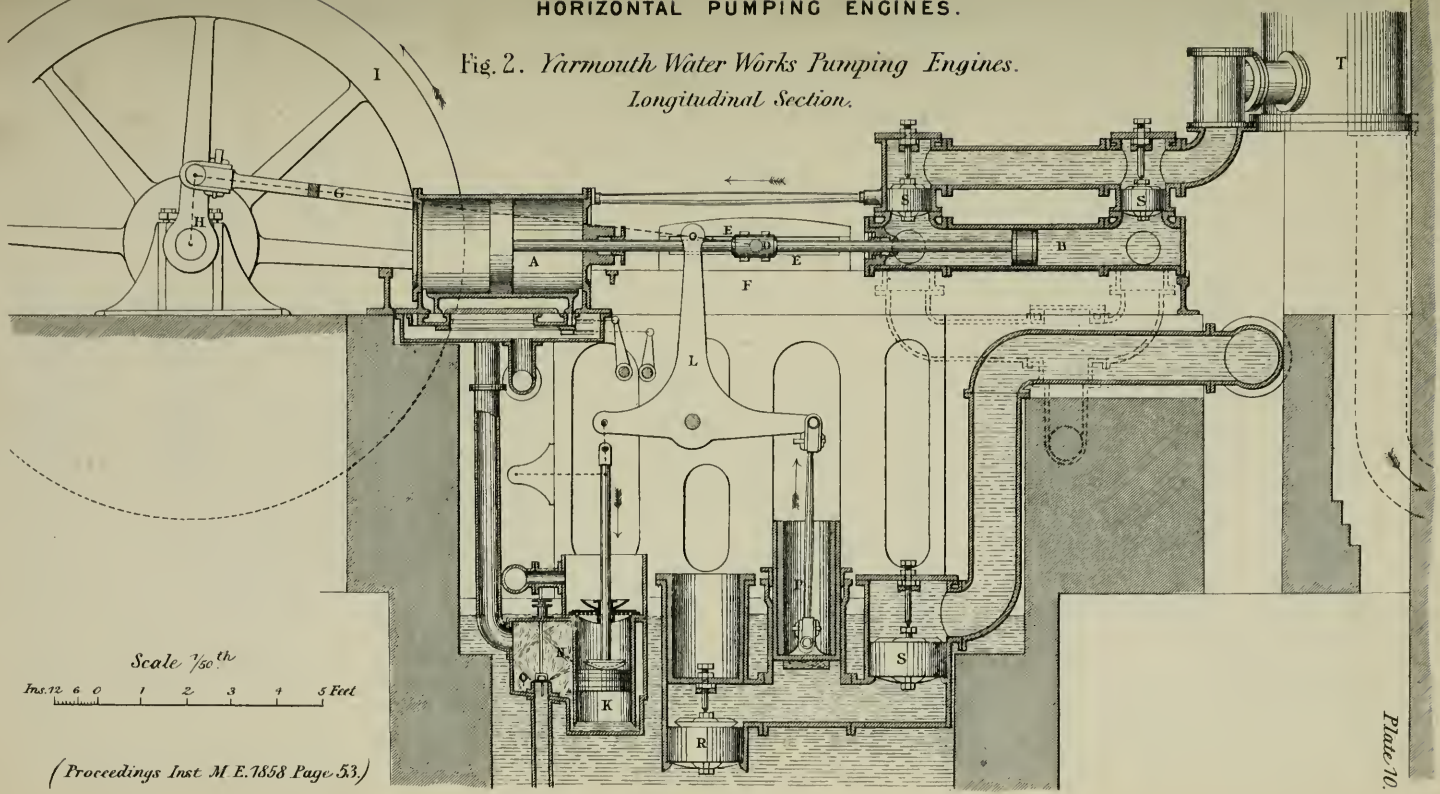
(Proceedings Inst M E. 1858 Page 49)

Plate 9.

HORIZONTAL PUMPING ENGINES.

Fig. 2. *Yarmouth Water Works Pumping Engines.*

Longitudinal Section.



(Proceedings Inst M E. 1858 Page 53.)

Plate 10.

HORIZONTAL PUMPING ENGINES.

Fig. 3 *Crystal Palace Pumping Engines (Lower Establishment)*

General Plan.

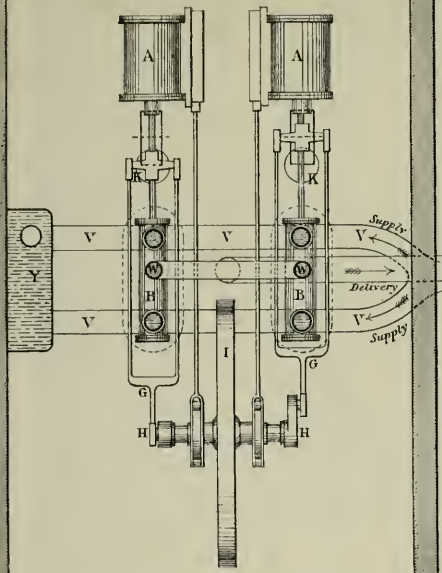
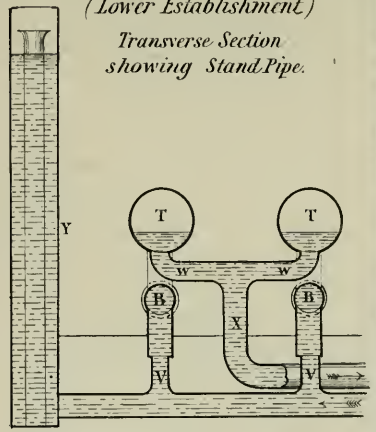


Fig. 4. *Crystal Palace Pumping Engines. (Lower Establishment)*

Transverse Section showing Stand Pipe.

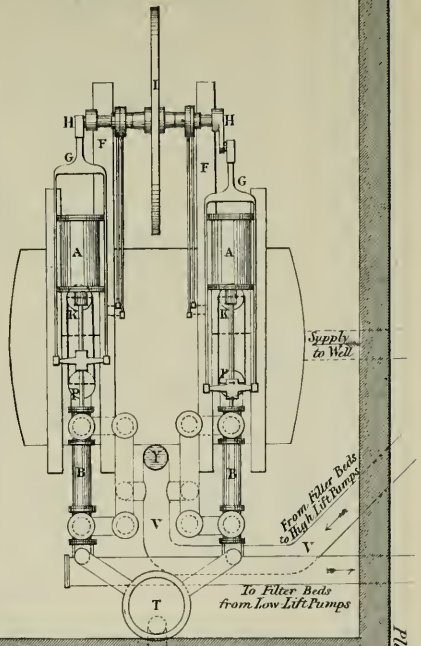


Scale 1/120th

0 5 10 15 20 Feet

(Proceedings Inst M.E. 1858 Page 49)

Fig. 5. *Yarmouth Water Works Engines. General Plan.*



Delivery Main from High Lift Pumps

Details of Pump Valves.

Crystal Palace Engines.
Fig 6. *Vertical Section.*

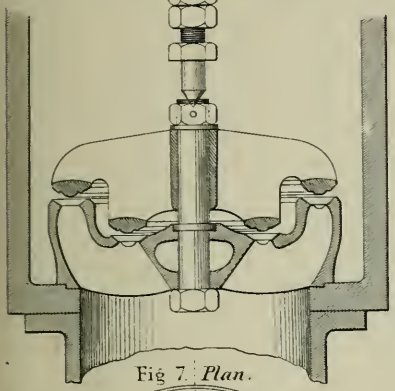


Fig 7. *Plan.*

Yarmouth Water Works.
Fig. 8 *Vertical Section.*

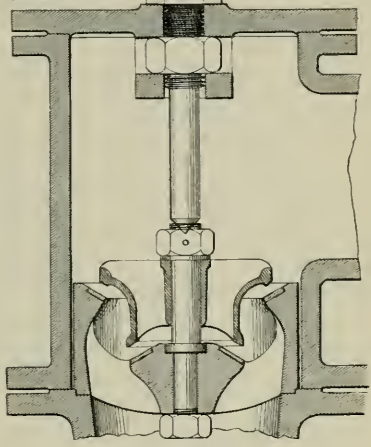
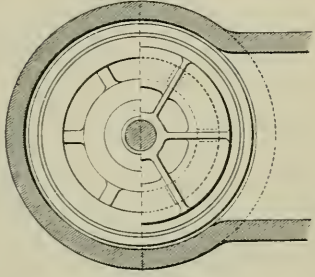
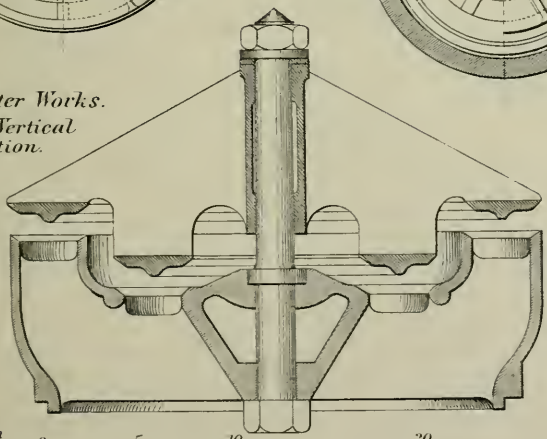


Fig 9. *Plan.*



Berlin Water Works.
Fig 10. *Vertical Section.*



Scale 1/10th 0 5 10 20 30 Ins.

Fig 11. *Diagram of Lift of Valve traced by the valve itself.*
Vertical Scale full size.

Beginning of Stroke. *End of Stroke.*

(Proceedings Inst M E. 1858 Page 50.)

Crystal Palace Pumping Engines

Fig 12. *Side Elevation of Cam for working Slide Valve.*

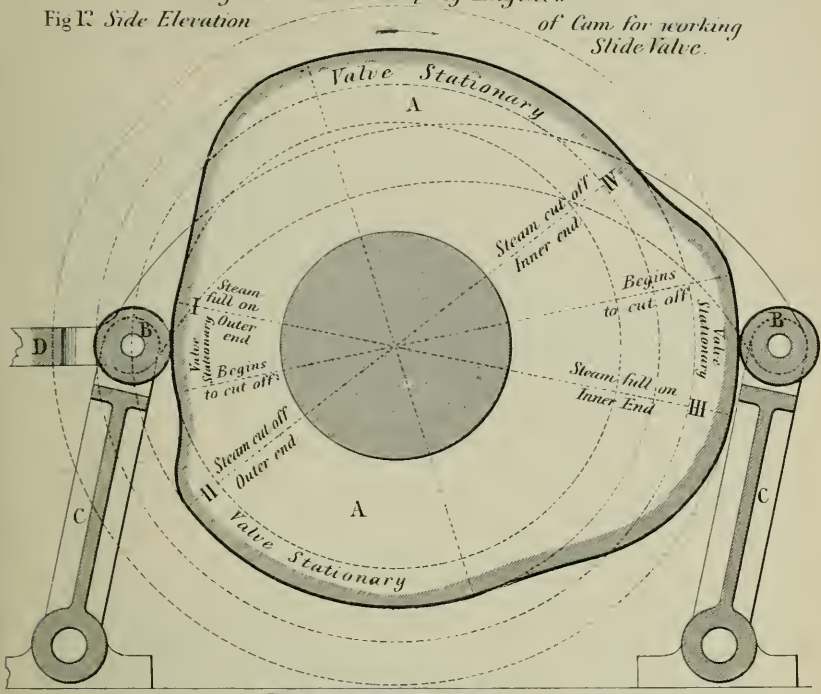


Fig 13. *Plan.* *Scale 1/10th*

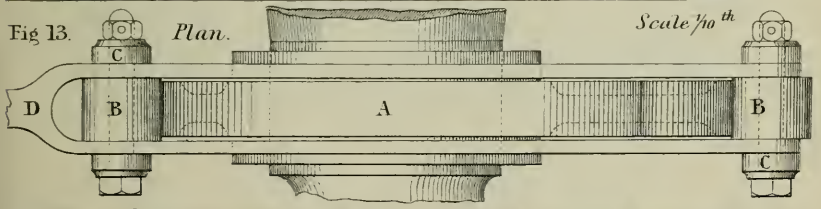
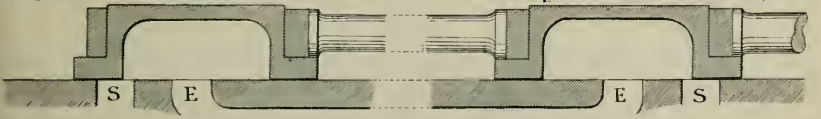
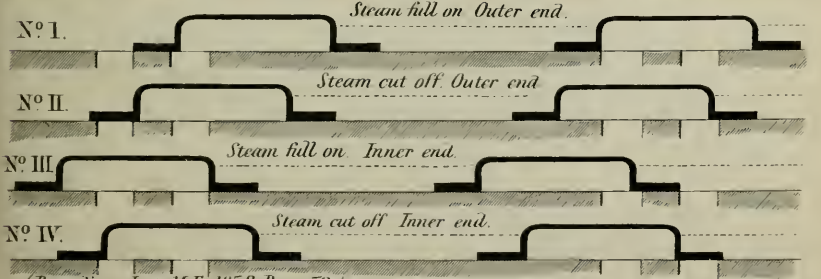


Fig 14. *Section of Slide Valve in middle position.* *Scale 1/10th*





(Proceedings Inst. M.E. 1858 Page 52.)

Fig. 15. *Indicator Diagram from Crystal Palace Pumping Engines.*

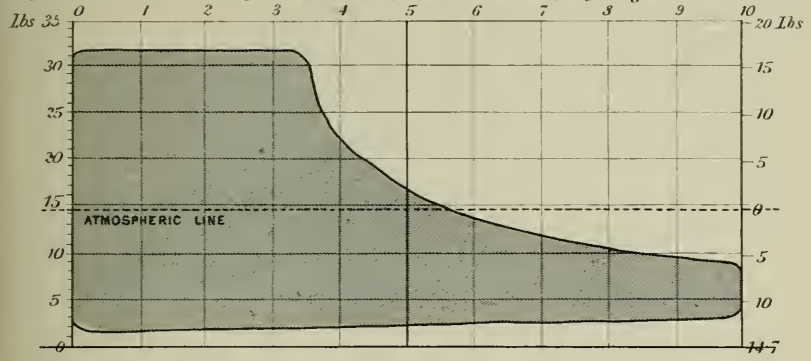


Fig. 16. *Indicator Diagrams from Yarmouth Water Works Pumping Engines.*

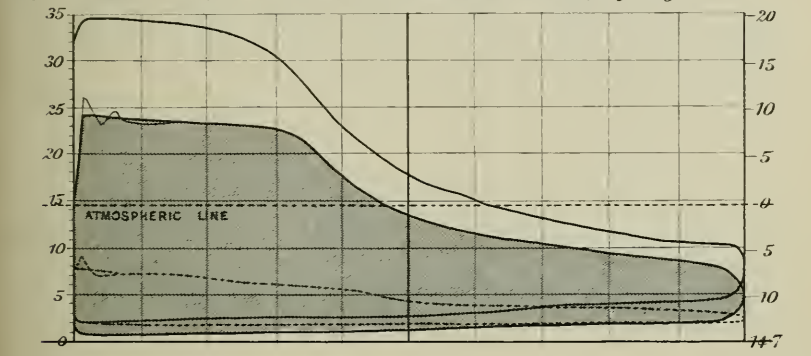
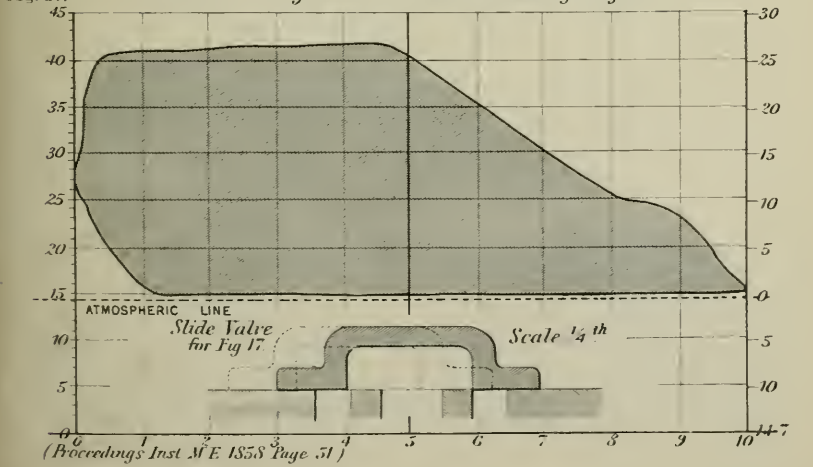


Fig. 17. *Indicator Diagram from Non-condensing Engine.*



(Proceedings Inst M E 1858 Page 51)

Fig 18. *Diagram showing the Velocity or Flow of Water from a Single-acting Pumping Engine without Flywheel.*

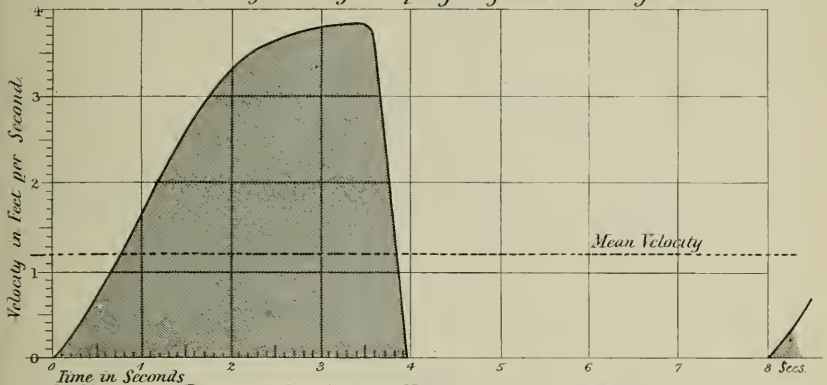


Fig 19. *Diagram showing the Velocity or Flow of Water from a Double-acting Pumping Engine with Flywheel.*

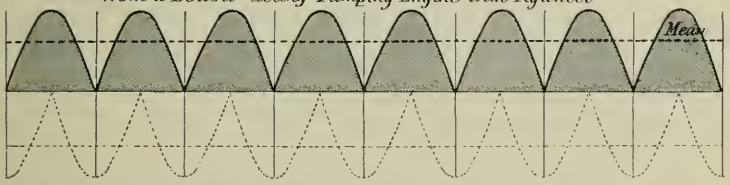


Fig 20. *Diagram showing the Velocity or Flow of Water from Two Double-acting Pumping Engines coupled at right angles.*

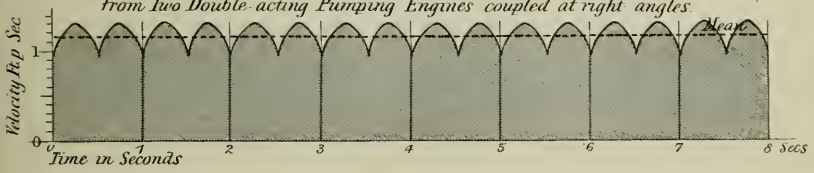


Fig 21.

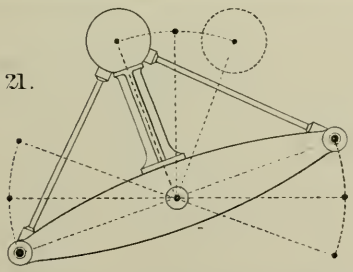
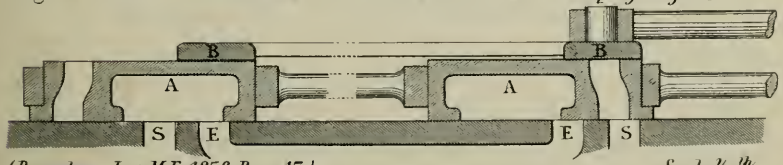


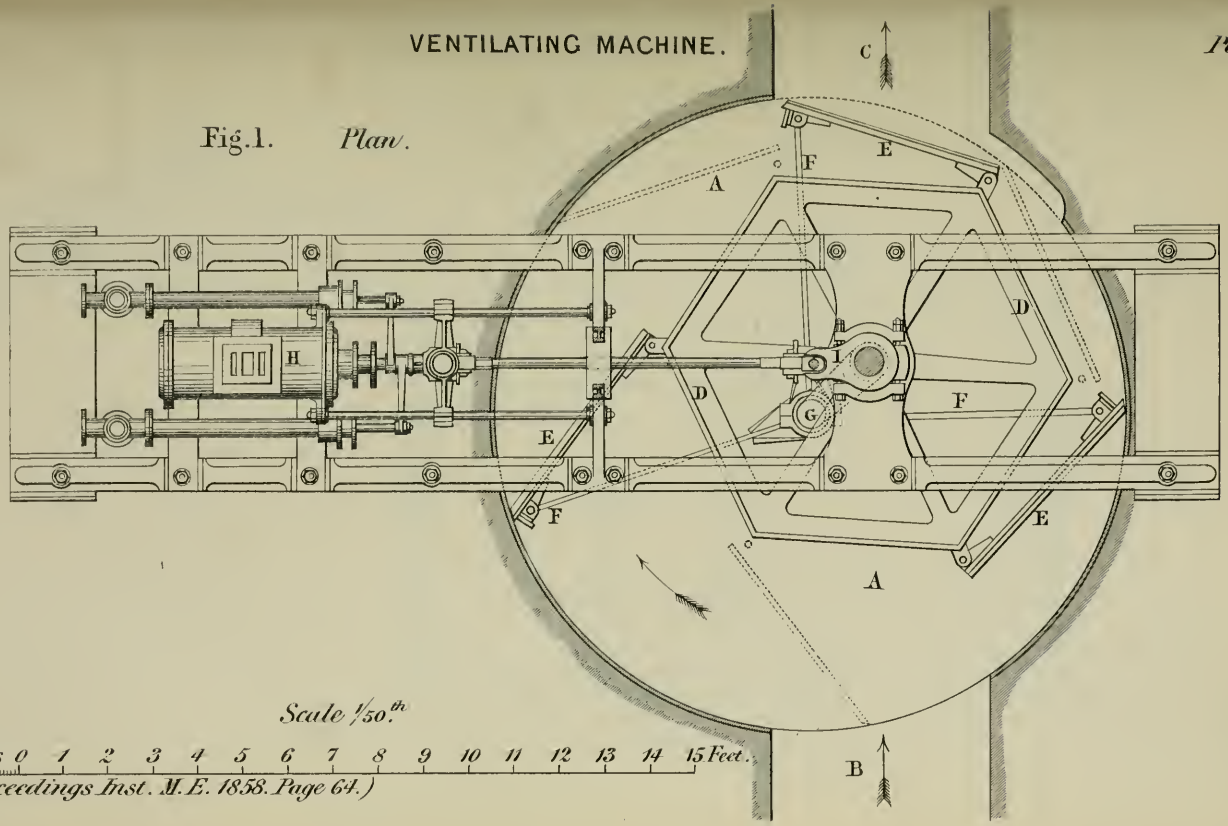
Fig 22. *Section of Slide Valve of Yarmouth Water Works Pumping Engines.*



(Proceedings Inst M E. 1858 Page 47.) *Scale ½0th*

VENTILATING MACHINE.

Fig.1. *Plan.*



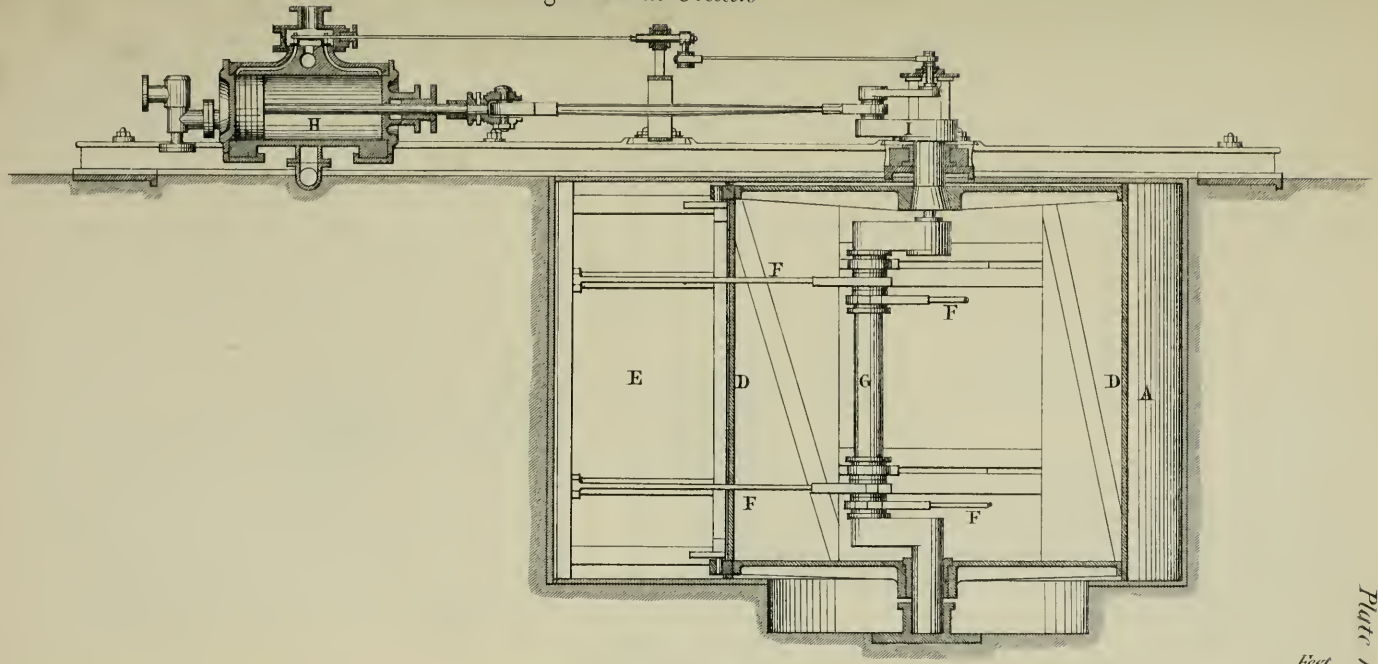
Scale 1/30th.

Ins. 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Feet.

(Proceedings Inst. M.E. 1858. Page 64.)

Plate 16.

Fig. 2. *Vertical Section*



(Proceedings Inst. M.E. 1858. Page 64.)

Scale 1/50th Inch. 6 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Feet.

Plate 17.

HYDRAULIC SHEARING PRESS.

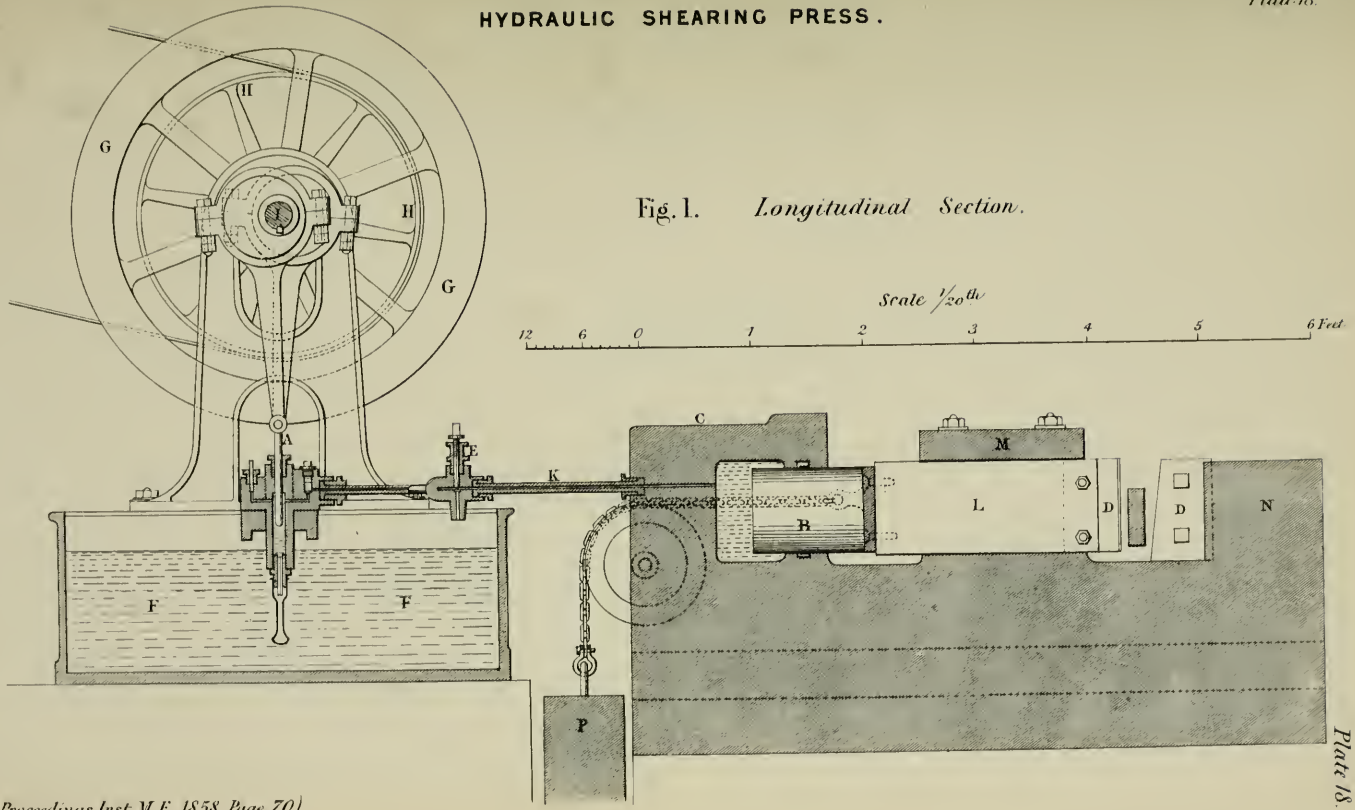


Fig. 1. *Longitudinal Section.*

(Proceedings Inst. M.E. 1858, Page 70)

Plate 18.

HYDRAULIC SHEARING PRESS.

Fig. 2. *Plan.*

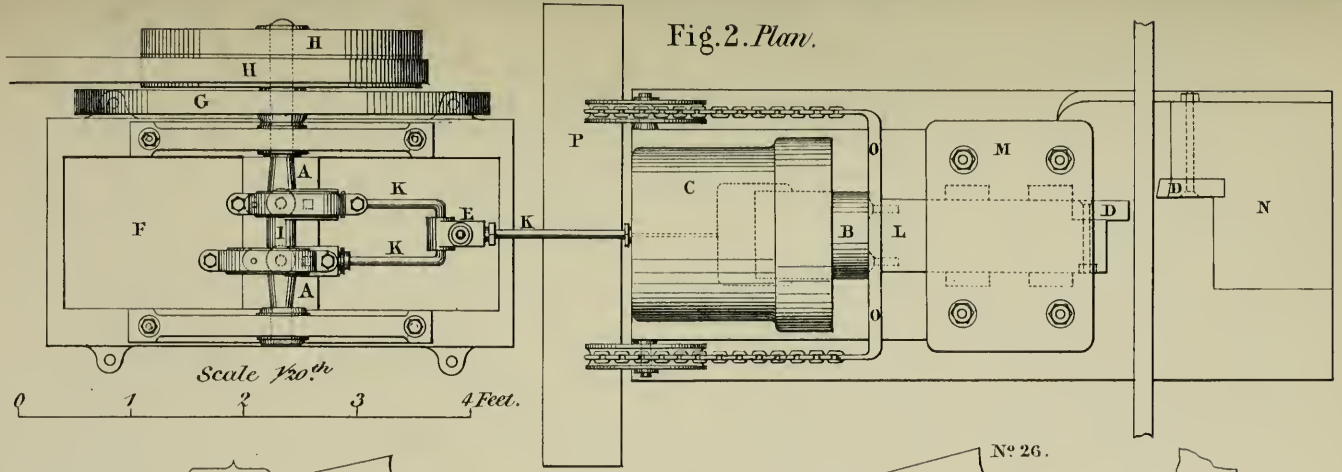


Fig. 3.

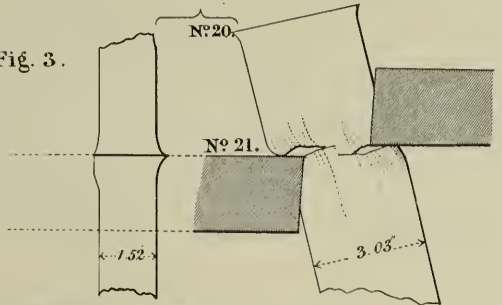
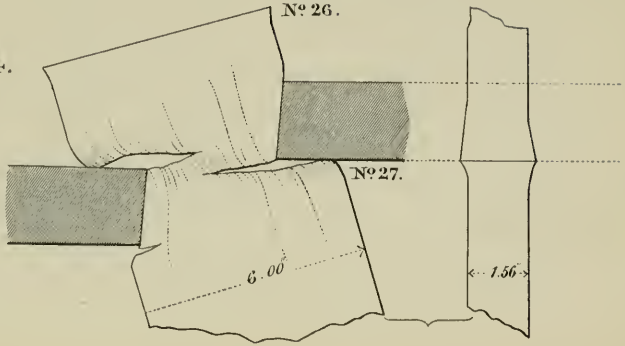


Fig. 4.



Scale 1/5th

(Proceedings Inst. M.E. 1858. Page 70.)

Plate 19.

PROCEEDINGS.

April 28, 1858.

The General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 28th April, 1858; Henry Maudslay, Esq., Vice-President, in the Chair.

The Minutes of the last General Meeting were read and confirmed.

The Chairman announced that the Ballot Papers had been opened by the Committee appointed for the purpose, and the following New Members were duly elected:—

MEMBERS.

Auguste Albaret,	Paris.
James Dees,	Whitehaven.
William Dempsey,	London.
Thomas Greenwood,	Leeds.
Thomas Elliot Harrison,	Newcastle-on-Tyne.
Thomas Howard Head,	Stockton-on-Tees.
Charles George Mountain,	Birmingham.
John Parkinson,	Bury.
Isaac Smith,	Birmingham.
James Taylor,	Leeds.
William Williams,	Crewe.

The following Paper, by Mr. Edward A. Cowper, of London, was then read:—

DESCRIPTION OF TWO PAIR OF HORIZONTAL PUMPING ENGINES.

In offering to the Institution a short description of some Horizontal Pumping Engines recently constructed it should be mentioned that the author has done so at the request of the Council, but has been prevented by press of business from making the paper so complete in its details as he would have desired; as however he considers it the duty of the members generally to supply to the Institution records of any works they may have executed at all of a novel or interesting character, he trusts that any defects in the paper may be excused.

If it is desired to work any steam engine economically, it is of course necessary to work expansively, with high pressure steam if possible; and to maintain a good vacuum wherever condensation is at all practicable, so as to allow of the expansion being well carried out. To do this, it should always be borne in mind that the power of the piston varies so much between the commencement and the end of the stroke, that the inertia of a considerable weight for the power to act upon is absolutely necessary, to absorb the extra force of the steam at the commencement of the stroke, and give it out again towards the termination of the stroke by the retardation of the weight. This is done in an ordinary Cornish single-acting pumping engine by the unavoidable weight of the "plunger poles" or solid plungers of the pumps in the pit; or where the same engine is used for water works purposes the single plunger is loaded with a "balance bob," sometimes upwards of 40 tons in weight, which of course travels at the same speed as the piston. But in a pumping engine with a crank and flywheel, the weight to give the inertia is placed in the rim of the flywheel, and travels many times as fast as the piston, thus increasing its effect very greatly; and although it does not actually stop as the balance bob does, still it varies in speed quite enough to make up for the variation in power.

There are many Cornish pumping engines that have the steam very much throttled in its passage to the cylinder, with the express view of

preventing the high pressure steam from getting fully on to the piston and causing too great irregularity in the moving power; in some cases 40 lbs. steam in the boiler reaches the piston at only about 12 lbs. pressure, since the inertia of the balance bob &c. would not sufficiently absorb a greater moving force.

In pumping engines with a crank and flywheel the stroke of the pump is completely controlled; and this arrangement is now universally adopted by the best makers of water works pumping engines. The flow or velocity of the water is more regular with a single crank engine, even if worked as a single-acting engine; for the pause or dwell at the top and bottom of the stroke in a single-acting engine without a flywheel makes more irregularity in the flow of the water in the main than the crank motion does; then if the crank engine works double-acting, the flow of the water is of course much more regular; and when in addition to this a pair of such engines are coupled at right angles, the flow is so nearly regular that the ordinary air vessel makes it practically uniform. This is shown by the diagrams represented in Figs. 18, 19, and 20, Plate 15. Fig. 18 shows the variation in the velocity or flow of the water from a single-acting engine without a flywheel, the dotted line representing the mean velocity.* Fig. 19 shows the variation in the velocity of the water from a double-acting engine controlled by a flywheel, the straight dotted line representing the mean velocity; and the inverted dotted line shows the corresponding velocity of the water from a second double-acting engine working at right angles to the former one. And when these two are coupled together, as in Fig. 20, the result is seen to be a very slight deviation from the mean line, or in other words a very regular flow of water. It should also be observed that a pair of engines so arranged make many more strokes per minute than it is possible for an engine without a flywheel to do, and this again is another cause of the greater regularity of flow; and now that water works companies are more enterprising than formerly, and pump the water often to 6, 8, or 10 miles distance, regularity in the flow is a most important point, independent of any question of greater security with the mains, which are not so liable to burst or leak in consequence of the jerking of the water at each stroke of the engine. There is also some considerable advantage in having a pair

* The curve shown in Fig. 18 has been constructed from the actual velocities ascertained in experiments made by a Committee of the British Association with the author's father, the late Professor Cowper, upon the Cornish pumping engine erected by Mr. Wicksteed at the East London Water Works, Old Ford.

of engines in place of only one, since necessary repairs can be better executed by stopping one and letting the other continue to do its half of the work.

It may not be out of place here to remark upon the great advantage obtained in all beam engines working expansively from the inertia and momentum of the beam, particularly where the beam is made heavy, as it should always be in such cases; it then acts precisely in the same manner as the balance bob. With a view of effecting this object to a still greater extent, the author many years ago designed a plan of fixing a top weight on to the beam of an engine, at some height above the main bearings; so that not only should its inertia and momentum come into play, but its weight also should be lifted by the steam at the commencement of the stroke, and by its descent in the latter part of the stroke should again give out the force so absorbed; this would help many an engine that had not in the first instance been properly designed for much expansion, but in which expansion had been subsequently introduced. This arrangement is shown in the diagram Fig. 21, Plate 15, in which it will be seen that the weight will have to be lifted by the steam during the first half of the stroke, the force required being greatest at the commencement of the stroke where the leverage of the weight is greatest; in the latter half of the stroke the effect of the weight will gradually increase in the reverse order.

In Horizontal Pumping Engines there is one great advantage which makes them particularly applicable for certain situations, namely, that they require no large and massive engine house to form part of the construction; indeed the "heavy castles" that used to be required to carry beams and spring beams &c., and so form part of the engine, are not required at all for horizontal engines. When these are properly constructed, so that the strains between the pumps, steam cylinders, and crank shaft, are taken by the iron frame or bed-plate itself, all that is required is a horizontal foundation for a pair of engines to be fixed on, with a well in the middle for the air pumps and condensers &c.

In the present paper are described two constructions of Horizontal Pumping Engines designed by the author for pumping water at the Crystal Palace and at the Yarmouth Water Works; the former having been started early in 1854, and the latter in May 1855.

Fig. 1, Plate 9, is a longitudinal section of one of the two pair of engines at the Crystal Palace. The steam cylinders A, Fig. 1, are 35½ inches diameter by 36 inches stroke, and the pumps B are the same stroke and 21½ inches diameter; these are double-acting and placed horizontally, the bucket rods C being connected direct to the steam pistons by being keyed into the same crosshead D, which work in horizontal guides E in the frames F. A long forked connecting rod G is attached to the ends of the crosshead D, and extends to the crank on the flywheel shaft H beyond the pump, the two engines being coupled at right angles. The flywheel I is 14 feet diameter, and runs between the two engine frames F. Each frame is cast in one piece, in the form of a pair of longitudinal girders connected by cross girders; and upon this the steam cylinder A and pump B are fixed in a direct line, as shown in the plan Fig. 3, Plate 11, which represents an adjoining pair of engines, the same in general construction, only differing a little in dimensions from those shown in Fig. 1; an inner girder underneath is prolonged to carry the crank plummer blocks. The air pump K of the engine is placed vertically below, and worked by bell-crank levers L connected by links to the crosshead D, the stroke being half that of the steam piston. The air pump is 22 inches diameter, and the bucket and delivery valves M are india-rubber discs on gun-metal grids; there is no foot valve, the bucket dipping at each stroke into a well sunk in the bottom of the condenser N. The injection is admitted by a conical valve O in the centre of the bottom of the condenser, lifted by a regulating screw. The cold water pump P is worked from the opposite end of the bell-crank levers L, and its valves are india rubber discs on brass grids.

The main pumps B are of cast iron, bored out and lined with gun-metal ⅜ inch thick. The suction valves R are in chambers underneath the pumps at each end, and the delivery valves S in chambers on the top of the pumps at each end; they discharge into an air vessel T fixed over them, consisting of a horizontal cylinder with hemispherical ends, 3 feet 9 inches diameter and 8 feet 3 inches length. A glass water gauge U at the end of the air vessel shows the level of the water in it; and a small air cock is inserted in each suction pipe V, for the purpose of drawing a little air continuously to keep up the due supply in the air vessel. The delivery main W is carried down from the centre of each air vessel, the two mains uniting in the centre between the engines, as shown

in Figs. 3 and 4, Plate 11, and forming a single large delivery main X. A stop-back valve is provided to the delivery main W of each engine.

The pump valves R and S are shown enlarged in Figs. 6 and 7, Plate 12. They are ring valves of peculiar construction, and the seats have two annular openings, 1 inch wide each, for the passage of the water, the lower annular opening being 7 inches mean diameter and the upper one 13 inches diameter. The valve and seat are both of gun-metal, and the valve is guided by sliding on a fixed centre pin. The area of the two annular openings of the seating is 63 square inches, and a lift of $\frac{9}{16}$ inch is sufficient to give an equal area of passage for the water. This form of valve has the advantage of giving four openings for discharge, being at both the inner and the outer edges of each of the openings in the seating. The weight of the valve is 37 lbs., which gives a pressure of ·59 lbs. per square inch as the force required upon the area of opening for lifting the valve and holding it open, being equivalent to about 16 inches additional head of water. The weight of the valve is adjusted so that the velocity with which the water passes it, when open, shall not cause sufficient pressure to force it up against the stop; and the consequence is that the valve is always pressing steadily upon the water as if floating closely upon it, and shuts gradually without shock, as the upward motion of the water diminishes and ceases under the control of the crank. A similar valve designed by the author for a friend, and in use at the Berlin Water Works, is shown in Fig. 10, Plate 12; many other valves have also been made of this form, and all are working well. Fig. 11 is a diagram of the lift of the valve at the Berlin Water Works traced by the valve itself in actual working; the line was drawn on a sheet of paper moved horizontally by direct connexion with the piston rod, and the vertical dimensions in the diagram Fig. 11 are full size; the dotted line shows the theoretical lift of the valve as set out on the motion of the piston, that is on a line representing uniform division of space, showing the lift of the valve or proportionate area of opening required at each point of the stroke in order to maintain a uniform velocity of the water through the valve. From this it will be seen how very close the valve is to its seat, before the crank actually passes the centre or the motion of the piston is reversed; so that it is clear that with a crank engine, having valves with a low lift and always floating on the water, there can hardly be any blow whatever at the turn of the stroke.

The regular speed of the engines is 15 revolutions per minute, giving

a mean velocity for the pistons of the engines and pumps of 90 feet per minute, and a total delivery of 2827 gallons per minute from each pair or 5654 gallons per minute from the two pair. These engines and pumps are employed to raise the water from the lower reservoir or lake to the upper open reservoir in the grounds of the Crystal Palace, having a head of about 103 feet, for the purpose of supplying the intermediate fountains; they are fixed close to the lower reservoir, having only a short length of culvert and suction pipes. Another pair of pumping engines shown in the plan Fig. 3, Plate 11, of similar construction, only differing a little in dimensions, are placed at the lower level for supplying this lower reservoir; they are fixed at a low part of the grounds about 20 feet below the level of the lake from which they draw, in order that they may be out of sight. The suction pipe in this case is of great length, about 900 feet; and for the purpose of avoiding the objectionable shock that would have arisen from the alternation in velocity of this long column of water, a large "stand-pipe" Y, Figs. 3 and 4, is fixed at the end of the suction pipes close to the pumps. This stand-pipe is a rectangular cast iron tank, 7 feet 4 inches long by 2 feet 4 inches wide and 22 feet high, with the two suction pipes entering on one side at the bottom, after passing and being connected to the vertical suction pipes V of the pumps; a slight rise and fall only in the level of the water in the stand-pipe occurs at each stroke of the pumps, in consequence of the slight change in the velocity at which the water is taken off by the pumps; and a uniform motion of the water through the long suction main is thereby preserved. These engines were constructed by the late firm of Messrs. Cox and Wilson, of Oldbury.

In Fig. 15, Plate 14, is given the indicator diagram from the Crystal Palace pumping engines, showing the mean line during 5 minutes regular working, the extent of variation being included in the thickness of the line. The steam is admitted at a pressure of 18·0 lbs. per inch above the atmosphere, cut off at $\frac{1}{3}$rd of the stroke, and expanded down to 5·8 lbs. below the atmosphere at $\frac{1}{20}$th from the end of the stroke, giving a mean steam pressure of 5·76 lbs. above the atmosphere; the mean vacuum is 12·44 lbs. below the atmosphere, beginning at 11·8 lbs. at $\frac{1}{20}$th of the stroke, and ending at 13·0 lbs. The total mean pressure is therefore 18·20 lbs. per inch, giving 49·1 indicated horse power for the pair of engines at the speed of 15 revolutions per minute. This gives 89 per cent. as the useful effect.

The slide valves in these engines are single slide valves, as shown in section in Fig. 14, Plate 13, which represents the valve in its middle position, SS being the steam ports and E the exhaust. The valves are worked by a cam motion which is shown in Figs. 12 and 13, Plate 13. The cam A works between two rollers BB carried by two vertical rocking levers CC, which are linked together at the top by means of the curved and forked end of the horizontal valve rod D; the diameter across the cam is made the same in all positions, so that both rollers are constantly in contact with it, or in other words it "fits and fills." The outline of the cam is made of such a shape as to hold the valve stationary in four positions in each revolution, as shown in the diagrams Nos. I., II., III., and IV.; and it will be observed that the valve stands still in these positions half the total time of each revolution. The whole travel of the valve is $6\frac{1}{4}$ inches; it is moved first $2\frac{1}{4}$ inches from its extreme position, from No. I. to No. II. (or No. III. to No. IV.), to cut off the steam at $\frac{1}{3}$rd of the stroke of the piston, and then remains stationary with the exhaust $1\frac{1}{2}$ inch open until close to the end of the stroke, when the valve is moved the remaining 4 inches of its travel, from No. II. to No. III. (or No. IV. to No. I.), thereby opening the exhaust and opening the opposite port to the steam. The steam ports S are 2 inches wide by 10 inches long, and the valve has $1\frac{1}{8}$ inch lap at each end, as shown in Fig. 14, whilst the inside is open $\frac{5}{8}$ inch to each port at each end at one instant of time, that is to say it is $1\frac{1}{4}$ inch longer inside than the distance between the ports, as shown in Fig. 14.

The curves of the cam are arranged so as to move the valve at each portion of its travel with a *uniformly accelerated* motion during the first half of each movement, and a *uniformly retarded* motion during the latter half, so that it is started gradually from a state of rest as in the commencement of motion of a falling body, and then as gradually stopped again; and the speed of the motion being so much less than the velocity acquired by a falling body in the same time, the pressure required to produce the motion amounts to only about one fourth of the weight of the moving parts. The shorter movement of the valve is made in 27° of a revolution, and the longer movement in 62° of a revolution.

There is an arrangement in the cam rod, by which at the time of starting the engine the cotters at the end of the rod can be drawn up, and so leave the rod free to move to the extent of 1 inch, that is with $\frac{1}{2}$ inch

play each way; by this means, when the cam rod moves the valve rod is left behind $\frac{1}{2}$ inch, which leaves the steam on throughout the stroke by failing to cut it off entirely, so that the engine is started without expansion, although the opening of the port is small after the cam rod has moved to cut off the steam.

This valve motion the author has found to work with complete success; and whilst great economy of steam is obtained, the expense of a separate expansion valve is avoided; but in cases of very quick running engines the cam motion might be objectionable. He has obtained a very good result with an ordinary eccentric and slide valve, arranged to cut off well at half stroke by modifying the interior of the valve; making the inside opening considerably greater than the space between the ports, so that one port is open one fourth or even one half to the exhaust before the exhaust from the other port has closed. A valve of this form is shown in Fig. 17, Plate 14, with the accompanying indicator diagram taken from it with a non-condensing engine; in this case the steam is cut off at half stroke, and although the exhaust is open early the line of the figure drops very little below the full expansion line; and the advantage is gained of a good exhaust at the commencement of the return stroke, with small amount of compression at the end, the mean back pressure being only 0·91 lbs. There exists therefore no reason why the very cheapest high pressure engines should not be made to work expansively, by cutting off at half stroke, or a little later according to circumstances; and in fact almost any high pressure engine could be altered to do so.

Fig. 2, Plate 10, is a longitudinal section of the pair of pumping engines at the Yarmouth Water Works; and Fig. 5, Plate 11, is a general plan to a smaller scale. These engines are employed for forcing the water to a high level reservoir at a distance of several miles; they are nearly similar in construction to those previously described, with the addition of a low-lift pump P fixed vertically under each engine, employed to pump the water from the well under the engine, which is supplied with water from a collecting reservoir (Ormsby Broad), on to a set of filter beds. These pumps P are $18\frac{3}{4}$ inches diameter with 18 inches stroke, and are worked from the opposite end of the bell-crank levers L that work the air pumps K of the engines; the height of lift is only 20 feet. As these low lift pumps are only single-acting plunger pumps, the plungers

are loaded so as to equal nearly half the head of water; thus half the work is done when the plunger is rising.

The steam cylinders A are 24 inches diameter with 36 inches stroke, and the high-lift pumps B worked from the same piston rod are 9 inches diameter with 36 inches stroke. A forked connecting rod G is carried from the crosshead D to the crank H, and the flywheel I 12 feet diameter works between the two horizontal frames F of the engine. The high-lift pumps B are supplied with filtered water by a main V, Fig. 5, from the filter beds; and as there is some head of water on them, a stand-pipe Y is arranged on the end of the main V, to allow of a slight fluctuation of the level of the water, due to the small variation in the rate at which the pumps take the water. Two cast iron girders under the frame of each engine span across the well, thus making a continuous foundation for the engine frame to lie on; the two inside girders are continued to carry the crank plummer blocks.

The pump valves are shown enlarged in Figs. 8 and 9, Plate 12. They are of gun-metal, with a seat of cast iron faced with gun-metal, and are double-beat valves, having the small seat at the bottom, instead of at the top; this allows of a central pin to act as a guide, and is so far a great advantage, as there is no danger of the valve hanging or sticking when it ought to follow the water freely. This form of valve was used at some water works under Mr. James Simpson some years ago, and the author believes was designed by Mr. A. Slate. The valves have two bearing faces, 5 inches and $8\frac{1}{4}$ inches inside diameter, with a vertical lift of $\frac{1}{16}$ inch. The total area for pressure is 26·3 square inches, and the weight of the valve is 18 lbs., requiring a pressure of ·68 lbs. per square inch to hold the valve open, equivalent to an extra head of water column of 19 inches.

The regular speed of the engines is 30 revolutions per minute, giving a velocity of the pump piston of 180 feet per minute. The height to which the water is pumped is 160 feet, including the friction of the mains.

The boilers, of which there are three, consist of a cylindrical shell 6 feet diameter and 20 feet long, with two fire tubes 2 feet 3 inches diameter; the flues returning outside along the sides of the boiler, and passing to the chimney along the bottom. By firing the two flues alternately and by the admission of air at the bridge the prevention of smoke is found to be practically effected.

These engines are required to be worked at present only one day at a time, twice per week, and the consumption of coal is consequently higher than it would be in constant work, from the brickwork &c. never getting properly hot. The consumption per hour, exclusive of getting up steam, is found to be 224 lbs., and the effective duty of the pumps being 56·74 horse power, the consumption of fuel amounts to 3·94 lbs. per horse power per hour on the net work done. The whole of the Yarmouth Water Works, where these engines are situated, were designed and carried out by Mr. J. G. Lynde, one of the members of the Institution; Messrs. Cochrane and Co. were the contractors for the pipes and engines, which latter were constructed by Messrs. Cox and Wilson, as sub-contractors, and the details and drawings were arranged by the author.

The indicator figure from these engines in ordinary work is shown by the shaded area in Fig. 16, Plate 14. The steam is admitted at a pressure of 9·0 lbs. per inch above the atmosphere, cut off at $\frac{1}{3}$rd of the stroke, and expanded down to 7·0 lbs. below the atmosphere at $\frac{1}{20}$th from the end of the stroke, giving a mean steam pressure of 1·05 lbs. above the atmosphere; the mean vacuum is 13·17 lbs. below the atmosphere, beginning at 12·5 lbs. at $\frac{1}{20}$th of the stroke, and ending at 13·6 lbs. The total mean pressure is therefore 14·22 lbs. per inch, giving 70 indicated horse power for the pair of engines at the speed of 30 revolutions per minute. This gives 81 per cent. as the net useful effect, exclusive of the friction of the engines and pumps. The upper full line in Fig. 16 was obtained by shutting off the steam partly from one of the engines, and putting most of the work on the engine from which the diagram was being taken; the mean steam pressure is 6·38 lbs. per inch and the mean vacuum 11·66 lbs., making a total mean pressure of 18·04 lbs. per inch. The dotted line shows the indicator diagram when the high-lift pump was detached, and only the low-lift pump worked; the mean total pressure is 2·94 lbs. per inch.

The slide valves, shown in Fig. 22, Plate 15, consist of first the ordinary working slides A driven by an eccentric, and secondly the expansion slides B on the back of the working slides A driven by another eccentric, so that the steam is cut off very close to the cylinder. The expansion slides B can be thrown out of gear to start with, but this is not found to be really necessary.

It must not be supposed that horizontal pumping engines are the most suitable for all situations, as for instance in the case of deep wells; but there are very many cases, particularly for water works, for which they are particularly applicable. In conclusion it should be stated that the engines described above are not brought forward as containing any very novel invention; but are simply described as works that have been executed, and that have answered the purpose for which they were designed.

Mr. W. S. Garland enquired what was the average duty obtained from the Yarmouth pumping engines; it appeared from the particulars given to be only about 60 million lbs. per cwt. of coal.

Mr. E. A. Cowper replied that the duty was about that amount in the present mode of working the engines, namely only one day at a time for 6 hours, and was of course considerably lowered by their not being in constant daily work; the present consumption of 3·9 lbs. of coal per horse power per hour net work done would most probably be reduced to a little below 3 lbs. in that case. The small size of the engines would also make the consumption rather higher than in larger engines.

Mr. W. S. Garland thought the pump valves in the Crystal Palace engines appeared rather small in proportion to the size of the pumps.

Mr. E. A. Cowper replied that the valves had each four openings for the discharge of the water instead of only two, giving a total area of 63 square inches when the valve was full open, which was quite large enough to allow a free passage of the water, as the engines were rather slow in the regular working speed of the piston. A very small amount of lift really took place in practice with that construction of double ring valve, on account of the free and direct passage given for the discharge of the water through the four openings; as was shown definitely by the diagram exhibited, which had been recently taken by Mr. Crampton from the pump valves at the Berlin Water Works.

Mr. W. S. Garland considered the rise and fall of the valve shown in the diagram was remarkably regular; he should have expected a much more sudden motion than was shown by the curve; the action of the valve was highly satisfactory, and it must work very quietly without any blow in shutting.

Mr. E. A. Cowper said that no blow whatever was perceptible in the working, and the diagram showed that the valve was very near the seat before the crank turned the centre, so that no concussion was produced in shutting. When the valve was so loaded as to keep it pressing constantly upon the water and prevent it from being thrown up against the stop, and the motion of the pump was also controlled by a crank, it was impossible to get a blow in shutting; he had found that in the present case a load of about $\frac{1}{2}$ lb. per square inch was sufficient with that form of valve at the ordinary speed of working, on account of the small lift of the valve. In the case of the old butterfly valves, the valve was shut by the column of water endeavouring to return, instead of by its own weight, and therefore shut with a violent blow; and the difficulty was greatly increased by the suddenness with which the motion of the water was checked at the end of the stroke in engines without a crank.

Mr. G. F. Muntz enquired whether the full extent of lift of the valve was shown in the diagram taken from the Berlin valve, as it seemed very little lift for so large a valve.

Mr. E. A. Cowper replied that the diagram showed the full extent of the actual lift of the valve, which was shown to be less than $\frac{1}{2}$ inch in working; but the whole clearance was $1\frac{1}{2}$ inch before striking the stop. The diagram had been drawn full size by the valve itself, by means of a small vertical rod attached to the top of the valve, passing up through the valve chamber and through a stuffing box, and carrying a pencil at its upper end, which traced the diagram upon a board moved transversely with the full stroke of the pump piston. The stroke of the pumps was 3 feet, making 28 revolutions per minute, or 168 feet per minute speed of piston. He had had several of these valves in use for a considerable time, which had proved very satisfactory in working; but this was the first from which a diagram of the motion had been taken.

Mr. C. W. Siemens was acquainted with the pumping engines at the Berlin Water Works, where there were twelve powerful beam engines, coupled in pairs at right angles with flywheels, and working vertical pumps under a pressure of 160 feet head of water. The present double ring valves allowed an easy and unrestricted motion of the water, as the joint circumferences of the four openings gave a large area of passage with a little lift of the valve.

With regard to the employment of the crank and flywheel for pump-

ing engines, in place of the Cornish system of lifting the water by the weight of the plungers, it was true that a large flywheel with a great weight in the rim, running at a considerably higher speed than the weight in the Cornish engine, had the advantage of more *vis inertiæ;* but only a limited fluctuation in its speed was available, and the weight was never stopped as in the Cornish engine, where the whole weight of the pump rods was stopped and started again at each stroke. It was therefore to be expected that a greater economy could be obtained by the latter plan, in case of very great lifts, a larger proportion of moving power being absorbed at the commencement of the stroke, allowing the expansion to be carried to a higher degree by admitting of greater extremes of pressure in the stroke. He accordingly thought there were cases, such as pumping from deep pits, where the Cornish plan would prove the most economical, the pump rods falling gradually by their own weight and being then lifted by the free action of the steam in the cylinder; but for many cases, such as low lift pumps, the horizontal direct-action construction was preferable. He observed that the engines described had not been designed for such a high degree of economy as was attained in the Cornish engines, since the steam was cut off only at one third of the stroke; and there did not appear to be a steam jacket to the cylinders. He had found a great advantage in employing a jacket not only round the sides of the cylinder but also at the ends, and it was more important to have a jacket at the ends than round the sides; for on the steam first entering the cylinder, a much larger extent of surface was offered to it by the end than by the small portion of the sides then exposed. When the cylinder was not protected by a jacket, the end of the cylinder being cooler than the steam on first entering caused a portion to be condensed, which was partly evaporated again in the latter part of the stroke, when the pressure and consequent temperature of the steam was lowered by expansion. The effect of this generation of steam in the cylinder was to increase the pressure at the end of the stroke beyond that due to the expansion; and the line of the indicator diagram was thus raised in the latter part of the figure above the regular curve of expansion. But this did not appear to be the case in the indicator diagram from the Crystal Palace engines, which showed the steam entering the cylinder at a total pressure of about 34 lbs. per square inch, cut off at one third of the stroke, and expanded down to a final pressure of only 9 lbs. instead of 11 lbs. due to the expansion.

Mr. E. A. Cowper observed that there appeared from the indicator diagram to be a little loss of pressure at the end of the stroke, due to some other circumstance; the cylinders of these engines were made without steam jackets for economy in construction, but he always employed a steam jacket wherever practicable. He observed that the indicator diagram showed a very square cornered figure owing to the action of the cam motion, particularly on beginning to exhaust, the exhaust being open to the full extent at once. The cam motion proved highly satisfactory in the engines working at only about 15 revolutions per minute; but he thought it would not be applicable in that particular form for a high speed such as 100 revolutions per minute, since it would be liable to cause concussion and wear of the rods and joints.

The Chairman quite agreed in the value of the steam jacket and of protecting the ends of the cylinders. Marine engine cylinders used to be made with steam jackets and then lagged with felt and wood; the top and bottom were cast hollow and protected from radiation by these spaces being filled with sawdust or other non-conducting material.

He enquired whether the india ruber valves of the air pump were fixed tight on the centre pin, or whether they were free to revolve on their guides by the action of the water, to prevent the valve from always beating on the same place.

Mr. E. A. Cowper replied that the valves were not nipped tight by the centre pin, but were an easy fit upon it; if the india rubber discs were nipped in the centre, they were liable to cockle up on the edge, and the shape was thereby injured; and when the shape was injured in fixing, they would not work well afterwards: but when the shape was uninjured and they were left just free, they worked satisfactorily and were very durable, and he thought they made the best air pump valves. He had had these valves at work in other engines for a year and a half, and they appeared still in as perfect order as when first put in. The conical injection valve used in the condenser gave a highly efficient action in condensing the steam; it threw a thin conical sheet of water into the condenser with the full pressure due to the vacuum, or 20 to 25 feet head of water; the water striking against the sides of the condenser was well distributed throughout the chamber, and a vacuum of 13·6 lbs. below the atmosphere was by this means maintained, giving a back pressure of only 1·1 lb. per square inch on the piston.

The CHAIRMAN observed that the first india rubber valves were fixed tight on the centre pin, so as to work always in the same position on the seat; but they had failed by becoming completely cut through by the bars of the grid after wear. Some valves had lately been tried with the bottom grid dished a little, the sides inclining upwards at an angle of 22° or 25°, the india rubber valve being also made of the dished form; this allowed a more free action of the india rubber disc, with less injury to the material.

Mr. JAMES BROWN remarked that the passage of the water through the grating caused the valve in rising to have a twisting action, preventing it from falling always upon the same part; and it was the invariable practice to make these valves easy on the spindles in the engines constructed by Messrs. James Watt and Co.

The CHAIRMAN observed that when the grid was dished all round, the disc rose bodily and seemed to twist a little in falling, which prevented the india rubber from always beating on the same place.

Mr. G. F. MUNTZ enquired what was the highest speed at which the engines could be worked without any concussion being produced in the double ring valves of the pumps.

Mr. E. A. COWPER replied that the Yarmouth pumps were worked at a speed of 180 feet per minute; those of the Crystal Palace engines had a regular speed of only 90 feet per minute, but they had been worked at 20 to 21 revolutions per minute, or 126 feet per minute, without any concussion of the valves being perceptible, the weight of the valves being sufficient to cause them to follow the water closely at that speed. If the pumps were required to be worked at a high speed or under a great head of water, the weight of the valves should be increased so as to give a pressure of 2 or 3 lbs. per square inch, instead of only a little more than $\frac{1}{2}$ lb. as in the present instance, in order to reduce the height of lift of the valves, and the extra pressure would involve the loss of only a small additional head of water.

The CHAIRMAN asked what was the difference in principle between the double ring valves now described and the plan of ring valves that had been tried before in marine engine air pumps and had been found to answer well, consisting of two separate rings, each rising independently and guided by a number of bolts holding a fixed ring which prevented their rising too high, the valves being of an inverted T section.

Mr. E. A. Cowper said the main point of difference was the greater relative length of the centre guide, whereby greater steadiness of motion was obtained. In the valves with two separate rings there were two short separate guides working upon the centre spindle, which were liable to cant and get jammed crossways in falling, if the valve were not sustained in a truly horizontal position; but in the double ring valves of the Crystal Palace pumps the guide was a long tube on the centre spindle, $4\frac{1}{2}$ inches long and $1\frac{3}{4}$ inches diameter, giving a proportion of height of $2\frac{1}{2}$ times the base, and thereby ensuring a steady fall of the valve. The action might be illustrated by that of a long narrow drawer, which would slide smoothly if pushed in endways; whereas a short wide drawer would stick, owing to the line of thrust being within the angle of friction. The ordinary form of double-beat valve was also partly liable to the same objection; for although the length of guide was considerable, its diameter was so large as to exceed the length, the base consequently subtending a large angle; the valve was therefore not so safe from getting jammed in closing, and did not fall so freely as if steadied by a longer guide; and, in the case of an engine without a flywheel, if the valve stuck at all it caused the engine to come down with a run. With the double ring valves however, in consequence of the greater relative length of guide obtained, there was scarcely any wear of the guide or of the centre pin, and the valves worked very steadily.

The Chairman asked whether there were many pumping engines working the pumps horizontally.

Mr. W. S. Garland did not know of any others working the main pumps in that manner; some engines had been made at Soho working the air pump horizontally but not the main pumps.

Mr. Samuel Lloyd considered a great advantage was gained in the flywheel pumping engine from the capability of working at even double the speed of a beam engine, and it was also much safer from accident; a case had occurred at their own works where the pump valve gave way in a beam engine of 60 or 80 horse power, and caused the breakage of the beam and much mischief, which would have been prevented by a crank and flywheel to the engine.

The Chairman observed that in a pair of 50 horse power high pressure direct-acting engines with vertical cylinders, constructed by Messrs. Maudslay Sons and Field for pumping from the Nile in Egypt

for the purpose of irrigation, the cylinders of which were 28 inches diameter with 6 feet 6 inches stroke, the piston rod was continued downwards and connected direct to the pump rod below, without either beam or flywheel, and worked a pump of 36 inches diameter and 6 feet 6 inches stroke.

The 40 horse power high pressure engines erected on the South Devon Atmospheric Railway by the same firm were constructed with a flywheel, the pair of engines being coupled together, and they worked well, they had vibrating cylinders 33 inches diameter and 6 feet stroke, and the air pumps for exhausting the air from the tube were also vibrating.

Mr. W. S. GARLAND remarked that a superiority had been found in economy in a flywheel pumping engine compared with a Cornish engine. In the case of a pair of flywheel engines erected for the New River Company at Stoke Newington near London by Messrs. James Watt and Co., the result of nine months working gave 8 to 10 millions per cwt. more duty than the average performance of the best Cornish pumping engines at water works, and 11 millions more duty than the double cylinder engines working at the same establishment.

The CHAIRMAN enquired the size of the engines, and whether the cylinders were well protected from radiation.

Mr. W. S. GARLAND replied that they were beam engines having 60 inch cylinders with 8 feet stroke, making 10 to 12 revolutions per minute, worked with steam at 30 lbs. per inch above the atmosphere, cutting off usually at $\frac{1}{5}$th of the stroke with the means of doing so at $\frac{1}{10}$th, and expanding down to about 10 lbs. below the atmosphere; the cylinders had steam jackets and were well cased. Each engine had two pumps of the "plunger and lift" kind, the outer pump having a plunger of 22 inches diameter and 7 feet stroke, and the inner one a plunger of $30\frac{1}{2}$ inches diameter and 4 feet 9 inches stroke; both working under a head of from 80 to 83 feet of water.

The CHAIRMAN proposed a vote of thanks to Mr. Cowper for his paper, which was passed.

The following Paper, by Mr. Samuel Lloyd, Jun., of Wednesbury, was then read :—

DESCRIPTION OF LEMIELLE'S VENTILATING MACHINE FOR MINES.

Good ventilation is admitted to be of the first importance in the working of mines; it neutralises and removes causes of accident which too often prove fatal to the miners, and produces an atmosphere favourable to their health and activity. The constant formation of noxious gas necessitates a powerful and regular ventilation, capable of removing it as soon as formed. These two conditions in ventilation are indispensable to produce favourable results; for in the case of a powerful but irregular ventilation, the gas may accumulate and give rise to serious accidents; but on the contrary, if the two conditions of power and regularity be united, the gas would then be carried off without intermission and all danger would be avoided.

The regularity of the coal seams in this country, and the ease with which they are worked, have contributed to the continuance of the old system of ventilation by the rarefaction of the air in the shaft by means of furnaces. This mode is without doubt the most simple; but under certain circumstances it is accompanied with danger, and serious accidents may and do arise, even with the greatest attention. An explosion might so derange the furnace as to prevent its being used. Also in many mines irregularities in working the furnaces, variations of the atmospheric temperature, and the distances and difficulties in the air passages, are frequent causes of irregular ventilation. In shallow pits, and even in deep pits habitually worked at a high temperature, little increase in the quantity of air in the mine can be obtained to meet sudden requirements; and in case of extended workings additional shafts are the only means of producing the requisite supply.

When the shaft is heated to the extreme, say to 360° or 390° Fahr., it is calculated that it produces theoretically but a small percentage of the effect obtained by steam power; 27 fathoms of depth giving only about $2\frac{3}{4}$ per cent., 55 fathoms $4\frac{1}{2}$ per cent., 80 fathoms $6\frac{1}{4}$ per cent., and 110 fathoms 9 per cent. If the shafts are used for drawing coals, the temperature rarely exceeds 104°, in which case the results obtained

are more favourable, being theoretically about $5\frac{1}{3}$, $10\frac{2}{3}$, 16, and $21\frac{1}{3}$ per cent. respectively, and with a pit 325 fathoms deep may reach as much as 64 per cent. If it be taken into account that the practical results differ widely from those arrived at by theory, it will appear that in pits varying from 50 to 125 fathoms in depth furnace ventilation is neither the most economical nor the most efficient. Many ingenious attempts have been made to obviate these objections, by the use of some mechanical apparatus for the purpose of ventilation.

Ventilation by mechanical apparatus of simple construction has the advantage of regularity; and if the machine be sufficiently powerful, produces a more uniform current of air than can be obtained by the ordinary furnace ventilation. The first cost of erections must be more expensive; but the prevention of danger, and the greater amount of work which the men would be capable of doing with improved ventilation, would more than compensate for the increase in the first outlay. Objections have been felt to the use of machinery for the ventilation of mines owing to the liability to derangement and the consequent stoppage of the supply of air; whereas with furnaces the shaft being heated continues to work for some time after an accident. In practice however it has been found that, with machines on the exhausting principle, the air and gases of the mine being in an expanded condition immediately contract in volume on the sudden stoppage of the machinery, and for a time the further issue of gas from the coal is checked.

The ventilating machine described in the present paper, having been extensively used for some years in the collieries of the north of France and Belgium, and proved successful in working, appeared a desirable subject to be brought under the consideration of the members of the Institution, as a means of accomplishing mechanical ventilation. The machine is the invention of M. Lemielle of Paris.

This ventilating machine is shown in Plates 16 and 17; Fig. 1, Plate 16, is a plan with the covering of the circular chamber A removed to show the machine; Fig. 2, Plate 17, is a vertical section.

The machine consists of a circular chamber of masonry A, which communicates by an air passage with the shaft of the mine on one side B, and on the other side C with the exterior air. In this chamber revolves a drum D, placed eccentric with the circumference of the chamber, to which

are attached three or more vanes E moveable at their base, the outer edges of which are kept in close proximity to the circumference of the chamber by means of the connecting rods F attached to the shaft G fixed in the centre of the chamber A and consequently eccentric to the revolving drum D. Motion is given to the drum by a horizontal steam engine H of simple construction, connected direct to a crank I fixed upon the top of the drum. The rotation of the drum causes each vane in succession to pass the opening B leading from the mine, shutting in a portion of the air between that vane and the preceding one, which air is carried forward and discharged at the outlet opening C, not being able to pass round on the other side of the drum. Thus the rotation of the machine causes a continuous discharge of the air from the shaft of the mine. The intermediate position of the vanes E is shown dotted in Fig. 1.

The first application of this apparatus was made in 1853, but previous to 1855 it was little known, being in the mean time only under trial experimentally; but after the Paris Exhibition of that year, at which the machine was shown, its adoption became rapid, and it is at present in operation at upwards of ninety mines in France and Belgium. The government engineers of both countries have at different times tested the effect of the apparatus in work, as regards the proportion that the quantity of air drawn in or discharged bears to the internal capacity of the machine, and also as to the safety of the apparatus; and from the various trials it has been found that the loss in the discharge of air does not exceed from 10 to 20 per cent. of the theoretical volume of the apparatus, the loss depending to a certain extent on the state of the air passages in the mine. The small amount of this waste is accounted for by the slow speed of the ventilator, which makes only 20 to 30 revolutions per minute, the discharge of air between the vanes being nearly complete, and the escape insignificant. The various ventilating machines previously used had to revolve with great velocity to produce any considerable current of air; and some having complicated machinery are liable to rapid deterioration; whereas in this apparatus all gearing is dispensed with.

In mines of great depth where the ventilation is difficult, the machine required to discharge 25,000 cubic feet of air per minute at 35 revolutions need not exceed 20 horse power; and for 75,000 cubic

feet per minute at the same speed, one of 50 horse power would under ordinary circumstances be sufficient; but in determining the power the distance to be travelled and the dimensions of the air passages have of course to be considered. Owing to the simplicity of the engines, the repairs are trifling; they require only what is common to all engines to ensure their good working, namely, cleaning and oiling.

These ventilating machines have been at work for 3 to 4 years in Northern France and Belgium; they have worked well from the first, and continue in good order without having caused any inconvenience from stoppage and repairs. A great advantage possessed by steam power over the furnace ventilation in case of accident is that the speed of the apparatus may be increased in an emergency, and thus a larger quantity of air may be drawn through the mine, thereby considerably diminishing the effects of an accident, whether it proceed from an explosion or downfall. The machinery being on the surface is independent of accidents, and entirely under the eye and control of the attendant. An essential point to be observed is that this ventilator can work up to a vacuum of $4\frac{1}{2}$ inches of water; and consequently in many mines where $2\frac{1}{2}$ inches could not be exceeded by the old system, the adoption of this machine has placed them in a more favourable position.

The following trial of the working of one of these ventilating machines was made on 28th January 1856 by the French government mining engineer, M. Dormoy, at the St. Mary's mine, near Ainche, Department du Nord, belonging to the Anzin Mining Company, the largest colliery in the North of France. The machine employed was 14 feet diameter of chamber and 7 feet depth, driven by an engine of 15 horse power; the shaft was 7 feet diameter and 680 feet deep, and the total course that the air travelled was about 3 miles; the quantity of air discharged was measured by Combe's anemometer. The ventilator at first revolved at the rate of 21 revolutions per minute; after that the velocity was increased to 37 revolutions. Eight successive experiments were made of which the following were the results. At 21 revolutions per minute the ventilator discharged 16848 cubic feet of air per minute with a vacuum of 0·8 inch of water; and at 37 revolutions discharged 25920 cubic feet per minute with a vacuum of 2 inches of water. The theoretical discharge calculated upon the dimensions of the machine

was at 21 revolutions 18576 cubic feet per minute, and at 37 revolutions 32724 cubic feet per minute; so that the loss while revolving slowly was 10 per cent., and at the increased velocity 21 per cent., giving a mean of 15 per cent. loss with an ordinary velocity.

Amongst the mines in France and Belgium at which these ventilating machines have been more than three years in constant work may be mentioned—the Société de Sclessin near Liège, where 9 of the machines are now in use; the Société Marihaye et Female Grande à Seraing, and the Société des Produits à Jemmeppes near Fleunus, each using 4 of the machines; and the Compagnie des Mines d'Anzin, where 3 of the machines are in use.

Mr. F. Laurent exhibited a working model of the machine, showing its construction and action.

Mr. Samuel Lloyd remarked that the subject of mechanical ventilation by means of a fan had been brought before the Institution at a former meeting; but the venilating machine now described acted more on the principle of a pump, the vanes acting as rotating pistons directly propelling the air with a slow motion of only about 30 revolutions per minute, instead of discharging it by centrifugal force which required a high speed. The machine need not be placed close to the shaft to be ventilated, but might be connected with it by an air tunnel, so as to have the steam cylinder as near the boiler as possible.

Mr. Frederick Smith enquired what would be the cost of the ventilating machine for one of the ordinary coal pits of the district, of about 30 acres in extent, with a 7 feet shaft.

Mr. S. Lloyd said the cost of the whole machine including the steam engine would be about £450 or £475.

The Chairman enquired whether there were any of the machines at work in this country.

Mr. F. Laurent said there were not any at present at work in this country, but one was being made for trial; there were now a large number in France and Belgium, which had proved highly satisfactory in working.

Mr. E. A. Cowper enquired what advantage there was considered

to be in this machine as compared with the ordinary fan, which had been used successfully for the purpose of ventilation. The degree of vacuum required was small and easily attained with a fan, and a slow velocity of revolution was practicable if a fan of large diameter were used. The machine now described appeared more complicated in construction; and for mechanical ventilation he did not think any apparatus so suitable as a fan driven direct by an engine, such as had been described at a former meeting.

Mr. S. Lloyd said the advantages of the machine now described were considered to consist more particularly in its direct action in pumping the air, and the slow motion, preventing risk of getting out of order.

Mr. E. A. Cowper remarked that a slower motion would involve a greater cost of construction for the same power, from the increased size requisite. A fan of 15 feet diameter driven at 120 or 150 revolutions per minute would discharge a very large quantity of air, and a high percentage of duty was obtained from fans of good construction when not very small in size, while the absence of a complication of parts was greatly in their favour. Some of the ventilating fans had been at work upwards of two years night and day, without requiring to be stopped for repairs of any kind.

Mr. G. F. Muntz enquired whether any experiments had been made to ascertain the relative power and cost in driving the ventilating machine as compared with a fan, to deliver the same quantity of air.

Mr. F. Laurent was not aware that any experiments by way of comparison had been tried; but from the slow motion of the machine and its direct action in discharging the air, he thought the power required to work it must be less than with the fan; and in the fan the sudden blow given by the vanes to the air at its entrance occasioned a loss of power; and the high velocity of the air at its discharge must reduce the percentage of useful effect. The first of the machines erected in France had now been at work 4 years, working continuously day and night for six days in the week, the pits not being worked on Sundays; but no stoppage had been required for repairs or from accident, and the machine could have been kept at work the seven days per week if required, without any difficulty from that cause.

Mr. S. Lloyd said that at a colliery in France near Valenciennes, where fans had been in use for many years to ventilate the pits, one of

the ventilating machines had been adopted at the last new pit, as being preferable to any fan that could be constructed.

Mr. J. Fernie observed that from the paper read at a previous meeting by Mr. Rogers, on the results of working of Mr. Nasmyth's ventilating fan, it appeared to be fully established that mechanical ventilation could be accomplished efficiently and safely even in a fiery mine; but there was still a strong opinion amongst mining engineers that the furnace was superior for regularity and simplicity and certainty of action. The machine now described was certainly more complicated in the number of parts, and he thought must be more expensive in construction and repairs than the fan, which appeared to him the simplest form of machinery for the purpose.

Mr. F. Laurent stated that the Société d'Anzin, the largest mining company in France, having 40 pits under their management, had 3 machines in operation; and gradually as the other methods of ventilation became used up, that of M. Lemielle was substituted, the company having determined to apply the machines to all their pits as occasion required.

The Chairman enquired what was the diameter of the largest machine at present at work, and the extent of mine ventilated by it.

Mr. F. Laurent replied that the largest machine was at a mine in Belgium, and was 14 feet diameter of the chamber and 9 feet depth, as shown in the drawing, discharging 30,000 cubic feet of air per minute; the total course of the air in the mine was about 10 miles length, and the air was drawn through a shaft about 3 feet 3 inches square.

Mr. E. A. Cowper asked what degree of vacuum was obtained for ventliation.

Mr. F. Laurent replied that a vacuum of $2\frac{1}{2}$ inches column of water was obtained at the end of the 10 miles course; the shaft was divided into two parts for the upcast and downcast currents, and there was that difference of pressure between the two sides of the shaft. The upcast shaft was used for the air alone, and the downcast for drawing the coals.

The Chairman proposed a vote of thanks to Mr. Lloyd and Mr. Laurent for the paper, which was passed.

The following Paper, by Mr. Charles Little, of Derby, was then read —

DESCRIPTION OF A HYDRAULIC SHEARING PRESS.

In the manufacture of bars or forgings from scrap iron one of the chief difficulties to be overcome is the cutting up of heavy scrap of large section, such as railway tyres, axles, engine frames, rails, ship's knees, &c., into pieces sufficiently small for the furnace, without their having to be heated in a furnace or smith's fire before they can be safely cut up by ordinary shears, such an operation involving a great loss of fuel, time, and labour, and consequently making a large item in the cost of manufacture. Several machines are at present in use for shearing scrap, but they are found to have some disadvantages either from too great first cost, weight, expensive foundations, liability to get out of order from the wear and tear of their working parts, or from their liability to breakage from improper management; this is frequently the case with the common lever shears, which travel so rapidly that there is barely time to place a large piece of iron near enough to the fulcrum before the shear descends, and from the angular position of its cutting edge at the time forces the bar to the extremity of the cutters, sometimes breaking the shears and not unfrequently injuring the attendant; this is most liable to occur when the iron is of a rounded section, or when it is painted or greasy. Another difficulty arises from there being no means of limiting or measuring the power of the ordinary machines when driven by cranks, cams, or eccentrics; and in case of accident the momentum of the fly-wheel prevents the machinery stopping suddenly; and if it is desired to strengthen the machine, this can be done only by a great increase of weight, necessarily requiring much more power for driving the machine.

Most of these difficulties have been overcome by the simplicity and peculiar construction of Mr. Eastwood's Hydraulic Shearing Press forming the subject of the present paper, which is shown in Figs. 1 and 2, Plates 18 and 19; Fig. 1 is a longitudinal section of the machine, and Fig. 2 a plan. This machine is so strong and self-contained that there is

little or no risk of breakage as in the ordinary machines; and large and unshapely pieces of iron can be cut up without in the least endangering the safety of the man employed to work the shears, since they are comparatively at rest during the whole operation, and the attendant has them so completely under control by means of a stop cock that they can be stopped instantaneously when required at any part of the stroke.

The two pumps AA are each $\frac{7}{8}$ inch in diameter, having 3 inches stroke; and the press ram B $9\frac{1}{4}$ inches diameter with a travel of 6 inches, this being a convenient size for shearing such scrap as has been referred to. The machine stands 2 feet 6 inches above the ground and occupies a space of 11 feet six inches by two feet 6 inches or about 30 square feet, this space including standing room for the pumps. The cylinder C and shears D are fixed horizontally, so that no foundation is required; and if thought desirable the machine can be placed on wheels, so as to be readily moved from one part of the works to another. The press being provided with a safety valve, absolute safety against overstrain is secured. In consequence of the shears being so little raised above the ground a tyre can be rolled alongside the machine and any part of its circumference dropped between the cutters D; the stop cock E from the pumps is then opened by the boy in charge, and the tyre can be cut up at the rate of 6 pieces per minute.

The pumps AA are fixed on the top of the tank F and are worked by eccentrics, which together with the flywheel G and fast and loose pulleys H, communicating by means of a strap with any prime mover, are fixed on to the horizontal shaft I running in bearings on the upright frames bolted down to flanges cast on the sides of the tank. The pumps are fitted with a safety valve and clack valve, and are connected with the press by pipes K, through which the water is forced into the cylinder C, thus forcing the ram B, having a cutter or shear D firmly secured to its prolonged end, against the bar of iron inserted between the moving and fixed shears, and cutting it through. The part L of the ram passing between the plates and jaws M is square and kept in its proper position by guide blocks let into recesses cast in the jaw pieces. The stationary shear D is bolted to an upright block N forming part of the same casting as the cylinder jaws, and bed. A crossbar O secured to the ram by screws has a chain connected to each of its ends, passing over two pulleys and carrying a weight P for the purpose of bringing the moveable

cutter and ram back, when communication between the pumps and cylinder is cut off by means of the stop cock. For working the machine all that is required is to start the pumps by throwing the strap on to the fast pulley; and the motion of the cutter can be regulated or stopped instantaneously by unscrewing the stop cock E.

Some experiments have been made by the writer with this press at Mr. Eastwood's works for the purpose of ascertaining the relative resistance of wrought iron to shearing in different thicknesses and proportions of width to thickness; this plan of press affording the opportunity of measuring the force actually employed at the moment of cutting by the pressure upon the hydraulic ram. The pressure was measured, as the most eligible method available, by hanging weights at the end of a long hand lever for working the force pump, the distance from the fulcrum to the pump being $3\frac{1}{4}$ inches, and from weight to fulcrum 78 inches, or 24 to 1; the area of the ram being $111\frac{3}{4}$ times that of the pumps, the total ratio of the actual pressure on the cutters to the load employed was 2682 times. All the experiments were made with hammered scrap iron of uniform quality, and the following general results were obtained.

Punching a 1 inch hole through $\frac{1}{2}$ inch and 1 inch bars required 36 and 69 tons respectively, or a mean of 22·5 tons per square inch of sectional area cut, as measured by the circumference of the hole multiplied by the thickness, (experiments No. 1 and 2.) Punching a hole 2 inches diameter through $\frac{1}{2}$ inch, 1 inch, and $1\frac{1}{2}$ inch bars successively required 65, 132, and 186 tons respectively, giving a mean of 19·4 tons per square inch of the sectional area cut, or 14 per cent. less in punching the 2 inch holes than in the 1 inch holes, (No. 3 to 6.)

Shearing flat bars was tried with sections 3 inches by $\frac{1}{2}$ inch and 3 inches by 1 inch; and the results gave a mean of 22·7 and 21·5 tons per square inch of sectional area cut, the difference being inconsiderable between the two directions of shearing, flatways or edgeways, (No. 7 to 12.)

In comparing the shearing of these sections, 3 inches by $\frac{1}{2}$ inch and 3 inches by 1 inch, with the punching of a 1 inch hole through $\frac{1}{2}$ inch and 1 inch bars, the result is nearly the same in both cases with the $\frac{1}{2}$ inch thickness, and with the 1 inch thickness about 5 per cent. less in shearing than in punching, the area of section cut through being about the same in the cases of shearing as in those of punching.

TABLE.

Experiments on Punching.

No of Experiment.	Diameter of punch.	Sectional area cut. Thickness and Circumference	Sectional area cut. Area.	Load, including lever.	Pressure on punch. 2682 times load.	Pressure on punch. Total.	Pressure on punch. Tons per inch of area cut.	Remarks.
	Ins.	Ins. Ins.	Sq. Ins.	Lbs.	Lbs.	Tons.	Tons.	
1	1	0·51 × 3·14	1·60	29·9	80192	35·8	22·4	22·5 mean
2	1	0·98 × 3·14	3·08	57·9	155288	69·3	22·6	
3	2	0·52 × 6·28	3·27	49·9	133832	59·7	18·3	
4	2	0·57 × 6·28	3·58	58·9	157970	70·5	19·7	19·4 mean
5	2	1·06 × 6·28	6·66	110·9	297434	132·8	19·9	
6	2	1·52 × 6·28	9·55	155·9	418124	186·7	19·5	

Experiments on Shearing.

No. of Experiment.	Direction of Shearing.	Sectional area cut. Thickness and Breadth.	Sectional area cut. Area.	Load including lever.	Pressure on cutters. 2682 times load.	Pressure on cutters. Total.	Pressure on cutters. Tons per inch of area cut.	Remarks.	
		Ins. Ins.	Sq. Ins.	Lbs.	Lbs.	Tons.	Tons.		
7	Flat	0·50 × 3·00	1·50	27·9	74828	33·4	22·3	22·7 mean	Parallel Cutters.
8	Edge	0·50 × 3·00	1·50	28·9	77510	34·6	23·1		
9	Flat	1·00 × 3·00	3·00	57·9	155288	69·2	23·1		
10	Edge	1·00 × 3·00	3·00	56·9	152606	68·1	22·7	21·5 mean	
11	Flat	1·00 × 3·02	3·02	49·9	133832	59·7	19·8		
12	Edge	1·00 × 3·02	3·02	51·9	139196	62·1	20·6		
13	Edge	1·80 × 5·00	10·20	175·9	471764	210·6	20·6	Flanged tyre.	
14	Flat	0·56 × 3 00	1·68	17·7	47471	21·2	12·6		Inclined Cutters (angle 1 in 8.)
15	Edge	0·56 × 3·00	1·68	27·7	74291	33·2	19·7		
16	Flat	0·90 × 3·37	3·03	22·9	61418	27·4	9·0		
17	Edge	0·87 × 3·32	2·89	47·9	128468	57·4	19·8		
18	Flat	1·06 × 3·02	3·20	41·9	112376	50·2	15·7		
19	Edge	1·06 × 3·02	3·20	56·4	151265	67·5	21·1		
20	Flat	1·52 × 3·03	4·61	69·9	187472	83·7	18·2		
21	Edge	1·53 × 3 03	4·64	77·9	208928	93·3	20·1		
22	Flat	1·39 × 4·50	6·25	74·9	200882	89·7	14·3		
23	Edge	1·38 × 4·50	6·21	92·9	249158	111·2	17·9		
24	Flat	1·73 × 5·30	9·17	127 9	343028	153·1	16·7		
25	Edge	1·73 × 5·30	9·17	172·9	463718	207·0	22·6		
26	Flat	1·56 × 6·00	9·36	116·9	313526	140·0	15·0		
27	Edge	1·56 × 6 00	9·36	143·9	385940	172·3	18·4		
28	Square	3·10 × 3·10	9·61	137·9	369848	165·1	17·2	Hammered iron.	
29	Square	3·10 × 3·10	9·61	129·9	348392	155·5	16·2	Rolled iron.	
30	Flat	1·80 × 5·00	10·20	82·9	222338	99·3	9·7	Flanged tyre.	
31	Edge	1·80 × 5·00	10·20	154·9	415442	185·5	18·2	Flanged tyre.	
32	Edge	1·70 × 5·25	10·57	149·9	402032	179·5	17·0	Flanged tyre.	

In the above experiments of shearing, cutters with parallel edges were used; but when the ordinary cutters with edges inclined to one another at an angle of 1 in 8 were employed, the force required in shearing was diminished, and considerably so in the case of the thinner sections when sheared flatways; and as bars are usually sheared flatways, a decided advantage is shown in favour of inclined over parallel cutters. The force in tons per square inch of section cut with the bars

	Flatways tons		Edgeways tons.		
3 × 1½ inch was	18·2	and	20·1	or	10 per cent. less flatways.
4½ × 1⅜	14·3		17·9		20
3 × 1	15·7		21·1		26
5¼ × 1¾	16·7		22·6		26
6 × 1½	15·0		18·4		18

A trial was also made of the force required to shear some hard railway tyres 1¾ inch thick, and the result was 185 tons total edgeways, and 99 tons flatways, (Nos. 30 and 31.)

A 3 inch square bar of rolled iron was also tried, and the force required was 155 tons total, against a total of 165 tons required for a hammered bar of the same section, (Nos. 28 and 29.)

Figs. 3 and 4, Plate 19, are drawings of the fracture of the bars in the experiments Nos. 20 and 21, 26 and 27.

In the accompanying Table are given the details of the several experiments.

Mr. E. Jones said they had had one of the machines at work for several months at Wednesbury with very satisfactory results; it effected a great saving of time and labour in cutting up heavy scrap, cutting up old railway tyres at the rate of 15 or 16 tons per day. A great advantage in the machine was that it could be instantaneously stopped at any point of the stroke; but in other machines the great momentum of the flywheel carried everything before it, causing extensive damage when an accident occured. In the hydraulic machine the safety valves could be weighted to any amount of force that the press was calculated to bear; and it required only a boy to attend to the pumps, and a man to shift the pieces for cutting.

Mr. G. F. Muntz considered the machine would be particularly valuable for large work, in consequence of being completely under control in working. The experiments in the paper he thought would give very interesting and valuable information to manufacturers in reference to shearing and cutting out ironwork, enabling them to ascertain more definitely the strain thrown upon the machinery.

Mr. J. Fernie had seen the machine at work at Mr. Eastwood's, and thought it possessed considerable advantages. The novel arrangement of the shears, in a horizontal position and close to the ground, allowed great strength of the frame and was a practical advantage in working for cutting up tyre bars; for there was a difficulty in the vertical machines in getting the tyre properly placed between the shears, but in this machine it could be readily bowled up and dropped into its place. The large shears used at the Midland Railway works for cutting up heavy scrap were three or four times as heavy and twice as expensive; but the hydraulic machine weighing only 5 or 6 tons, without any foundations or flywheel or connecting rods, cut up heavier sections of iron. The power of stopping the machine in working at any point of the cut gave it a great superiority over all other shearing machines; for although there was generally an arrangement in large machines by which the action of the tool could be stopped within $\frac{1}{16}$ inch of the work, yet if it once entered it must go through, and there was no means of preventing a break down if anything went wrong. The hydraulic machine was not intended for cutting the ends square, but fully answered the purpose of cutting up scrap iron for which it was intended, and seemed as great an advancement in shearing as the circular saw was for cutting hot bars.

Punching by means of a hydraulic press had been tried before he believed, and Mr. Hick of Bolton had entered largely into experiments on the subject, and had even punched the cotter holes in connecting rod ends. In the experiments described in the paper it was worthy of consideration, that, measuring by the sectional area of surface divided, the resistance to punching and shearing appeared to be about the same with moderate sizes; but with a large hole in thick iron the resistance to shearing was 5 per cent. less than to punching. He had witnessed several of the experiments, as had also the Secretary, and thought the results obtained might be relied upon.

Mr. E. A. Cowper thought the machine was a good application of power, and would prove extremely useful for the purpose it was intended for. He suggested that in the construction of the cylinder of the hydraulic press it would be preferable to cast the cylinder end convex instead of flat, to obtain a stronger form; an independent casting for the cylinder separate from the frame he thought would also be desirable, as more convenient for boring and repairs. He believed a hydraulic shearing press had been invented some time ago by Mr. May, and asked what was the difference in the present machine.

Mr. C. Little said this was an improvement on Mr. May's machine. In regard to the form of the cylinder, it was intended to make the end rounded in future machines, as that was certainly a stronger form. The object in casting the cylinder and the bed in one piece was to save weight, fitting, and the use of bolts; and at the same time to render the machine as portable as possible.

Mr. S. Lloyd mentioned that a breakage of the machinery in an ironworks at Wednesbury had recently occurred, attended with a heavy loss, which was clearly traced to a large shearing machine driven by a connexion with the rest of the machinery. The shear blade of this machine broke from a piece of iron happening to get wedged in between the steelings; an immense strain was thus thrown upon all the machinery, and though nothing gave way at the time a few weeks after one of the main shafts broke without any apparent cause; but when it was examined a crack was found, which evidently from the appearance of the rust had been caused by the strain thrown upon it at the time the shears broke down. This accident caused a loss of some hundreds of pounds, which would have been avoided if one of the hydraulic machines had been in use at the time.

The Chairman enquired what was the cost of the hydraulic shearing machines, and how large they had been made.

Mr. C. Little understood the cost of the machine shown in the drawings was about £200 including the pumps complete; that was the largest machine yet constructed, the ram being $9\frac{1}{4}$ inches diameter.

Mr. E. Jones said he had made a set of experiments several years ago on the force required for punching different sized holes in different thicknesses of plates, up to 1 inch diameter and 1 inch thickness; the force was applied by means of dead weights with a pair of levers giving a

total leverage of 60 to 1, so that 1 cwt. in the scale gave a pressure of 3 tons on the punch; the weights were added gradually by a few lbs. at a time until the hole was punched. The following results were obtained, which appeared to corroborate generally the experiments given in the paper with larger sizes :—

Diameter of Hole.	Thickness of Plate.	Sectional area cut through.	Total pressure on punch.	Pressure per square inch of area cut.
inch.	inch.	sq. ins.	tons.	tons.
0·250	0·437	0·344	8·384	24·4
0·500	0·625	0·982	26·678	27·2
0·750	0·625	1·472	34·768	23·6
0·875	0·875	2·405	55·500	23·1
1·000	1·000	3·142	77·170	24·6

The CHAIRMAN remarked that in the thinner plates the iron was more rolled, and might be expected to be denser and to offer more resistance to punching; moreover the thinner the plate the greater was the ratio of the hard skins to the interior metal, causing consequently a greater resistance per square inch of sectional area; the appearance of the punched specimens seemed to agree with this view of the case.

Mr. E. A. COWPER observed that in punching plates, if the bolster were made $\frac{1}{8}$ inch or $\frac{1}{4}$ inch larger in diameter than the punch, a conical hole was made, which in some cases could be made available as a rough kind of countersinking; in that case he expected there was less resistance than in punching a cylindrical hole, where the bolster fitted the punch properly.

The CHAIRMAN proposed a vote of thanks to Mr. Little for his paper which was passed.

The Meeting then terminated.

After the meeting a Steam Engine Indicator and Watchman's Detector was exhibited by Mr. Alfred Knight, of Birmingham; consisting of an eight day clock having two supplementary dials, made to revolve by the clock, each of them carrying a disc of paper divided into hours &c, ; on one of these discs a mark is made each time that

a given number of strokes is completed by the engine, which is connected by a coupling to a marking apparatus within the clock case, thus showing by inspection of the paper whether the engine has been kept at the correct speed throughout the whole time; whilst on the other disc a mark is made by pulling a handle connected with it, recording the times at which the handle has been pulled by the watchman.

A Standard Decimal Measure, of steel, 30 inches length, was shown, presented to the Institution by the late President, Mr. Whitworth: also a specimen from Mr. Whitworth of the new Decimal Wire Guage, proposed by him in place of the different guages hitherto in use; the new guage being made by Mr. Stubs, of Warrington, from standard templets prepared by Mr. Whitworth for the purpose.

PROCEEDINGS.

July 28, 1858.

The General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 28th July, 1858; John Penn, Esq., President, in the Chair.

The Minutes of the last General Meeting were read and confirmed.

The Chairman, on the occasion of taking the chair for the first time since his election, expressed his thanks for the honour that had been done him in electing him President of the Institution, and congratulated the members on the very prosperous and gratifying position of the Institution, the large accessions to the number of members, and the important and valuable character of the Proceedings. He trusted that all the members would render their aid and use their best exertions to advance the interests of the Institution.

The Chairman announced that the Ballot Papers had been opened by the Committee appointed for the purpose, and the following New Members were duly elected:—

MEMBERS.

Charles Edward Appleby,	Derby.
William Bouch,	Darlington,
John Wilkes Bower,	Smethwick.
William D. Burlinson,	Sunderland.
James I. Carson,	Stockton-on-Tees.
Joseph Crawhall,	Newcastle-on-Tyne.
John Harding,	Leeds.
John Hedley,	South Hetton.
Robert Hodgson,	Newcastle-on-Tyne.

George Hopper, ...	Houghton-le-Spring.
William Horsley, Jun., . .	Newcastle-on-Tyne.
François Laurent, . . .	Newcastle-on-Tyne.
James Mitchell, ...	Carlisle.
Thomas H. Murray, . . .	Chester-le-Street.
Jonathan Robson, . . .	Gateshead.
Joseph Scott, ...	Newcastle-on-Tyne.
Edward Brown Wilson, . .	London.
Nicholas Wood, . . .	Fence Houses.

HONORARY MEMBER.

William Humphryes Budden, .	Newcastle-on-Tyne.

The following Paper, by the President, was then read :—

ON WOOD BEARINGS AS APPLIED TO THE SHAFTS OF SCREW STEAM VESSELS.

At a former meeting of the Institution a description was given of the Wood Bearings that had been applied to the main bearings of screw shafts of steam vessels for the purpose of overcoming the serious difficulty experienced in the rapid wear of the ordinary brass bearings of those shafts; and the particulars were given of the experiments which had led the author to the employment of wood for this purpose. Since then the application of these wood bearings has been greatly extended; and prolonged experience has given a remarkably favourable result in their durability and the small amount of wear to which they are liable.

One of the first cases of the application of these wood bearings was in H. M. steam sloop Malacca, of 200 horse power, referred to in the former paper; these have now been at work $3\frac{1}{2}$ years, and the result has proved completely successful. Some specimens of the wood bearings from this vessel are exhibited to the present meeting, being some of the original strips of lignum vitæ that were put in after the vessel had been at work a short time with bearings of brass, as usual; but as the brass bearings showed immediate signs of wear, the same brasses were grooved out and the small strips of lignum vitæ sent and put in, and although the screw shaft bearings were somewhat cut and rough, it will be seen that the wear of the wood is very little after running 15000 miles. This may be considered a very severe test; and where the bearings are quite new when the wood is applied, the wear is really nothing.

It was found previously that where brass and brass were used in bearings the wear was so great that repairs had frequently to be made at great expense after a run of 2000 or 3000 miles. The weight on the screw bearings is about 70 lbs. per square inch; but from the experiments made it appears that ten times this weight might be applied with the wood bearings, and the wear would after running some years be practically

nothing. Where the wood has been applied to smooth bearings, or bearings in good order, no renewal has in any instance been required, although some vessels were fitted as long ago as December 1854. All the Government screw ships are now fitted with these bearings, and the system is coming into general use. It perhaps may be asked why iron shafts running on brass were not generally used: this would not do in wood ships, for it was found the iron bearings became rough and unequal from the chemical or galvanic action of the copper sheathing of the ship; but even in iron ships no bearing of whatever description has been found free from defects, except the wood bearing. It is always desirable where practicable to cover the iron shaft where it runs on the wood with a brass bush or covering; for an iron shaft, if the ship lies by idle for a few months, becomes rusty and tends to damage the bearing. This is the only advantage of covering the shaft with brass, for the wood wears as well on one metal as on the other, if kept constantly at work.

The mode of applying the wood bearings to the main bearings of screw shafts was described in the former paper, and shown in Figs. 1, 2, and 3, Plate 46 (Proceedings, January 1856); the wood being employed in narrow strips placed flatways of the grain, fixed in dovetailed grooves cut longitudinally in the brass bearings, with narrow spaces left between the strips of wood for a current of water for lubrication and to keep the bearing cool. This original construction is still adhered to and found quite satisfactory.

In Figs, 1 to 4, Plate 20, accompanying the present paper, is shown a more recent application of the wood bearings to receive the end thrust of the screw, by means of a large collar fixed upon the shaft at the screw or at any other desired position, which is capable in this construction of taking the entire thrust of the screw, thus removing the strain from the other bearings of the shaft or from the crank.

In this arrangement the pieces of hard wood, shown black in the figures, are fixed endways of the grain in a series of recesses or sockets in a brass disc A, through which the screw shaft B passes freely. This disc is either fixed to the stern post C of the vessel, as in Fig. 1, when the entire thrust is to be received at that point; or it is fixed to a cast iron bracket or pedestal D, as in Fig. 3, when it is required to take the thrust at a point of the shaft within the vessel. The pieces of wood project a little beyond

the face of the disc A, and work against a brass ring E, which is fixed on the front of the screw boss F, as in Fig. 1, or secured by a clip upon the shaft at the required position, as in Fig. 3. The disc A and ring E, Fig. 3, are both made in halves, bolted together by flanges for convenience of fixing.

When the wood bearings are outside, as in Fig. 1, the lubrication is effectually provided by their continued immersion in the water; and in the case of the inside bearings, the pedestal D is cast in the form of a trough for containing water, as shown in Fig. 3, by means of which the lower part of the bearing is kept constantly immersed in water.

These thrust bearings have been tried for some months, and promise to answer as well as the other wood bearings.

A further series of experiments on the use of wood bearings have been made with the same apparatus as those given in the former paper, consisting of a wrought iron axle, $1\frac{1}{2}$ inch diameter, immersed wholly in a trough containing 2 cubic feet of water, and driven by a pulley on the outer end, upon which were placed two experimental bearings pressed against the journal in opposite directions by two weighted levers (Proceedings, January 1856). The general results of the present experiments have completely confirmed those of the former series; and the trials have been further extended so as to ascertain the comparative results of working in salt water and fresh water, and with the water supplied in a continuous stream instead of complete immersion of the bearing in a bath of water as in the previous experiments. Also the effect of oil as a lubricator was tried instead of water with wood bearings. The general results are given in the following Table, the pieces of wood being placed sideways of the grain, except where otherwise stated :—

TABLE.

Table of Experiments on Wood Bearings.

July, 1858.

Description of Bearing.	Lubricating Material.	Area of Bearing.	Total Pressure.	Pressure per square inch.	Time of Running.	Result of Experiment.
	Water.	In.	Lbs.	Lbs.	H. M.	
Lignum Vitæ on Iron .	Salt	¼	672	2688	4 45	Scarcely worn.
Do.	Fresh	1	1250	1250	36 0	No signs of wear; original slight scratch not out.*
Do. (inferior wood) .	Fresh	1	672	672	7 0	Smooth and very little worn.
Do.	Salt	1	672	672	8 15	Smooth, little worn.
Lignum Vitæ on Brass.	Fresh	¼	1000	4000	0 5	No injury.*
Do.	Fresh	¼	672	2688	3 40	Not worn.
Do.	Salt	¼	672	2688	2 15	Little worn and smooth.
Do. (endways of grain)	Salt	¼	672	2688	4 15	Very smooth, not cut.
Hornbean on Brass. . .	Salt	¼	672	2688	0 50	Little worn and smooth.
Box on Brass	Salt	¼	672	2688	3 0	Smooth, not worn.
Elm on Brass.	Salt	1	672	672	8 15	Smooth, but little worn.
Pine on Brass	Salt	1	448	448	1 0	Not wearing.
Do.	Salt	1	672	672	4 30	Crushed by weight, but little worn.
Brass on Iron.	Salt	1	448	448	5 0	Cutting fast.
Brass on Iron.	Oil	1	448	448	3 30	Compelled to stop; shaft nearly red hot, emitting flame.
Kingston's Metal on Iron	Oil	1	224	224	0 40	Cool.
Do.	Oil	1	448	448	0 20	Metal ran out.
Lignum Vitæ on Iron .	Oil	1	224	224	0 50	Very hot and charred.
Do.	Oil	1	448	448	0 10	Charred and crushed to pieces; emitting smoke and flame.

* Experiments taken from former series.

From these experiments it appears that there was not any material difference between the use of fresh or salt water; it was found also that a continuous stream of water $\frac{1}{8}$ inch diameter gave exactly the same results as complete immersion, with the bearings of 1 square inch area used in the trials.

In reference to the use of oil instead of water, it appears that with copious oil lubrication a pressure of 448 lbs. per square inch with a brass bearing on iron required the shaft to be stopped in $3\frac{1}{2}$ hours, when it had become nearly red hot; and under the same pressure with water the bearing ran for 5 hours, but was then cutting fast. With lignum vitæ on iron, with copious oil lubrication, half that pressure or 224 lbs. caused the wood to become very hot and charred in 50 minutes; and under the full pressure of 448 lbs. the wood was charred and crushed to pieces in 10 minutes. Whereas with water lignum vitæ on iron ran with six times that pressure or 2688 lbs. per square inch for $4\frac{3}{4}$ hours with very little sign of wear.

In regard to the position of the wood, whether wearing endways or sideways of the grain, it was found that the endways position is about one fifth superior; but in either position the wood bearings are capable of sustaining without injury pressures far beyond those occurring in machinery, which may be taken to fall below 100 lbs. per square inch. Indeed, the softer woods have proved more than sufficient in this respect, and failed with the higher pressures from absolute crushing rather than from wear: thus pine on brass with 448 lbs. per square inch ran 1 hour without injury; but with 672 lbs. in $4\frac{1}{2}$ hours was crushed by the weight, though but little worn.

The Chairman explained the reasons that had originally led him to try the wood bearings, and said he had found the experience of the screw steamers showed that no metals would stand the wear to which the bearings of the screw shafts were subjected; and the case was made worse by the circumstance that iron running on brass could not be employed in the war steamers on account of the rusting when not at work, and also in wood vessels with copper sheathing they were obliged to use brass running on brass, on account of the galvanic action that took place with iron; but brass and brass did not agree in wear, and all the bearings were found to fail from rapid wear. Having had some experience many years before of the use of wood for bearings of other machinery, it occurred to him

that wood might answer for the purpose and remove the difficulty; and accordingly the experimental apparatus that had been described was prepared, and the experiments tried at once, and he found to his great surprise that wood was more than ten times better than any metals for the purpose. The wood bearings were at first kept working 100 hours continuously at the ordinary pressure of about 70 lbs. per square inch, which was about the pressure on screw bearings, but no impression whatever was produced on them; and higher pressures were therefore tried, in order to arrive at a definite result more speedily by ascertaining the limit at which wear would commence; but even with 4000 lbs. per square inch scarcely any wear was perceptible with the hard woods, though the pressure was thus carried to a far greater extent than any occurring ordinarily in machinery. Wood was consequently at once adopted for the screw propeller bearings, and had proved so thoroughly successful for this purpose that he did not know of a single instance in which any repairs had been required since the first application of the wood bearings nearly four years ago; for when once fitted the strips of wood remained with scarcely any sensible wear, when the journals were in good order to begin with. The specimens of wood bearings exhibited from the Malacca showed but slight wear after running 15000 miles, although the journals were somewhat cut and rough previously to applying them.

A great difficulty had been experienced originally in taking the end thrust of the screw shaft, and the metal thrust bearings caused great trouble by heating and rapid wear. In first employing wood for that purpose it was applied as a lining of the collars in the ordinary grooved bearings with several collars: but the plan now shown of taking the thrust by plugs of wood fixed endways of the grain was much superior; and allowed of the whole bearing being fixed outside, close to the boss of the screw.

With regard to other applications of wood bearings, he had tried them for the crank pin bearings of a 200 horse power marine engine; but although the wood worked very well as long as it was well supplied with water, there was not found to be any material advantage over the ordinary brass bearings, and it was given up, as there was the disadvantage that the wood did not bear any neglect in lubrication, and if the supply of water were accidentally stopped for a short time the wood took fire and the bearing was gone, since there was nothing to fall back upon as in solid metal bearings.

Lignum vitæ was used for the wood bearings, as the cheapest and most convenient hard wood that could be obtained, costing only about 2*d.* per lb.: another more expensive wood called grenadillo, a species of crocus, was indeed the hardest he had met with, so hard that it stopped the machine when tried under heavy pressures, and no impression could be produced upon it; but lignum vitæ stood far higher pressures than were required in practice, and seemed likely to last twenty years at least.

Mr. W. Froude asked what the coefficient of friction was found to be with the wood bearings.

The Chairman replied that the general result of the experiments appeared to be that the friction of wood on iron was about one fourth of that of brass on iron when water was used. A few refined experiments were made to ascertain the exact amount of friction of different kinds of wood; but the difference was too small to be of any practical importance. The power required with the wood bearings generally was very small; but $1\frac{1}{2}$ horse power was absorbed by the brass bearings, when under the heaviest pressure they would stand. A great difference of temperature was observed in the water in the experimental tank with wood and metal bearings: with brass bearings the water was nearly raised to the boiling point under heavy pressures; whilst with wood bearings after a rise of about 30° or 40° above the ordinary temperature the evaporation was sufficient to keep it at the same temperature.

Mr. C. W. Siemens observed that the increase of temperature of the water in the cistern enclosing the bearing would afford the most delicate test of the power, if it could be accurately ascertained; since the total heat absorbed was an exact representative of the total power consumed, 770 ft-lbs. or units of power absorbed producing 1 unit of heat in the water.

Mr. William Smith remarked that the use of wood for bearings had been practised by the old millwrights, but the velocity of the rubbing parts was always low and the whole surface of the bearing was in contact; but in the wood bearings of the screw propeller shafts the wood was in strips laid in grooves in the brass bearing with spaces between for lubrication by the water, and also the velocity and pressure were much greater. With regard to the circumstance mentioned in the paper that original scratches on the surface of the wood bearing had not been worn out after long continued use, he doubted whether this proved that no wear had taken

place, for a scratch would in some degree be acted upon with the general surface and go down with the wear, and so not become effaced from the worn surface of the bearing.

Mr. Henry Maudslay had much pleasure in confirming all that had been stated respecting the durability and complete success of the screw and after bearings lined with lignum vitæ for screw ships; they had proved of great value and were now universally adopted throughout the navy, from the smallest gunboats to vessels of 1000 horse power; and complete success had invariably attended their use. Also in the mercantile marine, the screw steamers formerly belonging to the General Screw Steam Shipping Company had run to Australia in 64 days and back for 3 or 4 successive voyages, under steam almost the whole way, without any perceptible wear of the wood in the stern bearings. In regard to any scratches made on the surface of the wood bearings, their tendency he considered would certainly be to wear smooth, and no scratch made obliquely as in the experiments could continue with the wear, as all particles that might be rubbed off were washed away by the water. In the stern tube bearings of screw shafts this was provided for by slacking back the gland of the stuffing box inside the deadwood at the end of the screw alley when first working, and letting the water run through in a continuous stream to wash out the bearings thoroughly; the gland was then screwed up again till only a small quantity ran through, sufficient for keeping up the lubrication of the bearing. The wood bearings used by old millwrights were, he believed, confined almost entirely to grindstones, where the pressure was comparatively small, and the application was easy since the water supplied to the grindstone could also be supplied to the bearings to keep them cool. In the screw steamers it had been thought at first that the action of the salt water upon the brasses was the cause of their excessive wear, and harder bearings were therefore tried; but it was found that the harder they were made the more hot they became, whereas with wood a hot bearing now never occurred.

Mr. W. Smith, in referring to the circumstances of scratches remaining on the surface of bearings, meant more particularly those in the direction of rotation, which had a tendency to continue when once formed. He had recently had an opportunity of seeing several of the slips taken out from the screw bearings of vessels at Portsmouth, and was surprised to find that so little wear was experienced in them even with the little attention they had received; since the adoption of wood bearings a hot bearing was now

unheard of, though so frequent an occurrence previously, and he could add his testimony to the very great improvement which had been effected by them.

The CHAIRMAN observed that he had once thought the wood bearings might be applicable for shafts of heavy machinery, such as rolling mills; but he doubted now whether they were suitable for such purposes, on account of the excessive pressure momentarily occurring when the plate or bar was going through the rolls, which was so great as sometimes to break the rolls themselves and would absolutely crush the wood; for the experiments showed that under great pressures the wood gave way by crushing, although the limit of actual wear had not been reached.

Mr. C. W. SIEMENS inquired how far the wood bearings might be applicable to railway purposes, for the axle journals or other bearings; the water required for lubrication might perhaps be supplied by pipes from the tender.

The CHAIRMAN said the great practical difficulty in any such application of the wood bearings would be the supply of water: no doubt so long as a copious supply could be maintained the bearings would work excellently, but any defect in the supply would rapidly cause heating, and the wood would then burn away. He doubted whether wood bearings were applicable to ordinary purposes in machinery, on account of the difficulty and inconvenience of the constant supply of water required. In the engine at his own works he had had the crank pin brasses plugged with wood for trial; but there was not any material advantage gained, and the wood was found to be no better than the brass bearings.

Mr. A. B. COCHRANE inquired whether there was likely to be any advantage in the use of wood bearings for the journals of fan shafts; the bearings of soft metal were found to wear well though the fans were driven at a high velocity.

The CHAIRMAN had not tried the wood bearings for that purpose, but there would be the objection against the use of water as in machinery generally.

Mr. HENRY MAUDSLAY thought nothing could be better than soft metal bearings for fan shafts, as the length of the journals could be made many times the diameter, so that the wear was very small; and for any small machinery travelling at a high velocity Babbitt's metal or any of the anti-friction soft metals was much the best.

Mr. G. F. Muntz observed that the general employment of wood bearings appeared to depend on the practicability of supplying the quantity of water requisite to keep them properly lubricated; if a small quantity were sufficient, such as only about twice as much as the oil at present required, the wood bearings might be extensively used with advantage; but with the large quantity of water that appeared necessary, their use would involve more difficulty and inconvenience than the present metal bearings.

Mr. Isaac Smith said that in consequence of the great amount of wear experienced with the ordinary gun-metal bearings in rolls working under heavy pressures, he had made trial of two pairs of rolls and their driving pinions, one having the brasses plugged with Babbitt's white metal, which had now been at work for two months, and in the other they were plugged with lignum vitæ, on the plan of Messrs. Olsen and Hipkiss of Birmingham for lubricating shafts; the plugs of wood were inserted endways of the grain in holes in the brass, and acted as sponges, absorbing a quantity of oil and keeping the bearing constantly lubricated, while the brass took the load; and no more water was used than ordinarily ran on the rolls. This plan had been tried only about three weeks at present, not long enough to give any complete result; but there appeared already to be a decided saving in the friction, as shown by the indicated power of the engine. Very heavy work was being done, and the rolls were screwed down to a very hard pinch; they were employed in rolling sheet steel for pens, the strips being rolled cold from No. 26 wire gauge down to very fine thicknesses, requiring a very great pressure, amounting probably to 5000 or 6000 lbs. per square inch on the bearings; and a single pair of rolls of 7 inches diameter and 9 inches length frequently absorbed as much as 12 to 15 indicated horse power, when reducing the steel to thin sizes.

Mr. W. Froude asked what was the velocity at which the rolls were driven; he supposed it must be small under so heavy a pressure.

Mr. I. Smith replied that one pair of rolls whose bearings were 4¼ inches diameter were driven at about 19 revolutions per minute, and the other pair with bearings of 4 inches diameter made 25 revolutions per minute, the body of the rolls in each case being 7 inches diameter and 9 inches long.

Mr. G. F. Muntz remarked that the ordinary bearings for rolls employed to give heavy pressure were not required to make more than 25 to 30 revolutions per minute. One advantage of wood bearings would be that they would not cut the journal if anything went wrong with the lubrication, as was the case with metal bearings. He asked what was the highest speed that had been tried with the wood bearings in the experiments.

The Chairman replied that the velocity of surface was about 260 feet per minute throughout the experiments, that being a little above the working speed of the shafts of screw propellers, and the experiments were made with special reference to the application of wood bearings for that purpose.

Mr. A. B. Cochrane observed that they were much indebted to the President for the valuable information afforded in the paper, and the important practical results he had obtained in reference to the wood bearings. He proposed a vote of thanks to the President for the paper, which was passed.

The following Paper, by Mr. William Froude, of Dartington, was then read :—

ON A NEW DYNAMOMETER AND FRICTION BREAK.

The annual exhibitions of the principal agricultural societies throughout the kingdom have done much to stimulate the exertions of manufacturers of agricultural implements and machinery, by exciting a keen competition for the prizes offered and for public approbation. And while the machinery thus submitted to competitive trial has undergone rapid improvements and has attained a high degree of mechanical excellence, it has become necessary that the societies in undertaking the office of judges should provide as far as possible adequate tests of comparative merit. One principal condition of excellence in machinery of every description is economy of power: and this condition specially invites the application of a testing apparatus, which shall be purely mechanical in operation, and shall record by a self-acting process the results of trials; and shall be at once accurate and intelligible in its action.

The machines brought forward for trial at the agricultural exhibitions may be classified under two heads: those which *consume power*, and those which *supply power*. Although that well known and most valuable instrument, the steam engine indicator, is capable of being applied with considerable accuracy directly to power supplying and indirectly to power consuming machines; yet in trials which are so closely contested as these, and where it is desirable that the conditions under which each machine is tried shall most nearly correspond with those under which it will have to perform its ordinary duty, it is obviously preferable to substitute for the indicator two distinct forms of dynamometer, one specially adapted to the power consuming class, the other to the power supplying class of machines. Moreover both forms of dynamometer should be so constructed as to determine the result of each trial in the gross, instead of as a unit which is to be subject to multiplication: so as in fact to record in an integral form the measure, in the one case, of the whole power consumed during the performance of a given task; and in the other, of the whole power developed by the combustion of a given supply of fuel.

Belt Dynamometer.—The first kind of Dynamometer now to be described is adapted for machines of the power consuming class, and is designed to record by a diagram the performance of any power consuming machine which is usually driven by a belt or can be so driven on the occasion of the trial.

In order to show how this object is accomplished, it is necessary to point out the conditions of force under which a belt transmits power to the machine which it drives. In the first place, the belt must possess a sufficient amount of fundamental tension to maintain the necessary adhesion upon the pulleys: and if the machine were entirely free from friction, and were once put in motion without any load or duty, this fundamental tension would continue equally great in both the leading and trailing sides of the belt. In the next place, if the machine be loaded (and the friction of the working parts always forms a portion of the load), the driving belt must be tighter on the leading side than on the trailing; otherwise the motion will cease on the application of the load. The difference of tension between the two sides of the belt which must be thus brought into action, in order that motion may continue while the resistance of the load is in operation, is the exact measure of that load; and therefore if this difference of tension be known, the power consumed can be calculated in exactly the same way as if the pulley were driven simply by a force of the same amount acting at the circumference. Thus the two elements of the power consumed will be—first, the actual force at the circumference of the pulley, or the difference between the tensions of the leading and trailing sides of the belt; and second, the distance travelled by this force, which is identical with the travel of the circumference of the pulley or of the belt itself. Hence the power consumed or the units of work expended during any instant will be the product of the difference in lbs. between the tensions of the leading and trailing sides of the belt at that instant, multiplied by the space in feet travelled by the belt during that instant.

In accordance with this view of the subject, the object aimed at by the writer in the construction of the dynamometer now to be described is to obtain by a direct process a continuous record of the difference of tension between the leading and trailing sides of the belt combined with the space travelled during each instant, throughout the period occupied in the completion of a given task; and if also the total time occupied be noted, these recorded data can be at once converted into average horse power

consumed. In the present instrument the difference between the two tensions is ascertained by a direct process closely analogous to that of weighing one against the other at the opposite ends of a scale beam; in such a manner however as to maintain the equilibrium not by adding weights to the lighter end, but by supporting the heavier end by a spring balance, the extensions of the spring measuring the excess of weight at the heavier end.

The construction of the dynamometer is shown in Plates 21, 22, and 23; Fig. 1, Plate 21, is a side elevation of the instrument, and Fig. 2, Plate 22, an end elevation, with portions of the framing omitted; Fig. 3 is a plan. Figs. 4 to 7, Plate 23, show portions of the instrument enlarged, to explain the construction. The power is supplied by the intervention of the pulley A, and is received and consumed by the pulley B of the machine under trial, the motion taking place in the direction indicated by the arrows. The belt by which the power is conveyed from A to B passes over the pulleys C and D, which are carried at opposite ends of the scale beam or swing beam E and are centered on it at equal distances from the centre F on which it vibrates. The upper and lower portions of the belt pass over the guide wheel G and are thus retained parallel, and do not deviate appreciably from that position though the swing beam E be made to move through an angle of many degrees from the vertical position. In case the pulley B of the machine be of larger diameter or at a higher level than the guide wheel G, a supplementary guide pulley H is employed to preserve the parallelism of the two portions of the belt.

In this arrangement the tight or leading side of the belt passes round the upper pulley C on the swing beam, and the slack or trailing side round the lower pulley D; so that the pulley C is pressed horizontally by the tension of the tight side of the belt, and the pulley D by that of the slack side. Now were these two tensions equal, the swing beam E would remain in equilibrium, and would rest indifferently in any position within a moderate inclination to the vertical line. But since they are unequal, the spring balance I, which supports the upper end of the swing beam, receives the pressure resulting from the inequality, and indicates the amount by its extension, this pressure being exactly the measure of the difference of tension between the tight and slack sides of the belt; and as the difference of tension varies with the varying duty performed by the machine

under trial, the extension of the spring will vary also correspondingly ; and these variations being recorded continuously or in an integrable form, together with the space travelled by the belt during the same instant, will furnish the measure of the power consumed. It has to be noticed that the total tension on each of the swing beam pulleys is double that of the respective portions of the belt, because the tension of the belt acts on both sides of the pulley; so that the spring balance indicates double the difference between the tensions of the tight and slack sides of the belt ; this is however allowed for by the mode of constructing the scale of tension on the diagrams, as afterwards described.

The apparatus by which the dynamometer is made self-recording consists of a cylinder K, Figs. 4 and 5, of suitable dimensions, mounted in a frame attached to the end of the instrument, which is made to revolve by means of a screw and worm wheels connected with the upper pulley C ; the screw is provided with telescope and universal joints, so as to allow of the vibration of the beam, one end of the screw resting on the moveable arm of the swing beam, while the other is carried by the frame in which the cylinder is mounted. Thus the revolutions of the recording cylinder represent on a reduced scale the revolutions of the pulley C, and therefore furnish a measure of the travel of the belt. At the same time the pencil L receives a motion direct from the swing beam E, being connected with the upper end of the swing beam by the cord J ; it is mounted in an arm which has a sliding motion parallel to the axis of the cylinder, and which is so placed that the pencil presses lightly on the surface of the cylinder ; the position of the pencil accordingly represents the position of the swing beam, or the extension of the spring balance. The tendency of the spring balance to oscillate above and below its proper position is checked by means of an oil cylinder M, Fig. 3, provided with a loosely fitting piston which is attached to the spring balance ; there is also a communication between the two ends of the cylinder by means of a passage fitted with a stop cock. The recording cylinder K is provided with a continuous sheet of paper, which is uncoiled from a lower cylinder ; and as it revolves, the pencil traces on the paper a line, or rather a curvilinear area, in which each increment in length represents the corresponding space travelled by the belt ; while the height at that point, measured from the datum line traced by the pencil when the spring balance is at zero, represents the stress upon the spring balance while the belt travelled through that space. The aggregate area included

in any length of diagram thus produced represents therefore exactly the units of work performed in that time; this is easily measured in the same manner as an ordinary indicator diagram, and can then be converted into units of work performed, when the scale by which the conversion is to be effected has been determined.

The swing beam E, by which the tension of the tight side of the belt is weighed against that of the slack side, should for convenience be so constructed that the belt can be slipped on and off the pulleys when required; and therefore the pulleys themselves must be overhung. The pulleys should also be relieved as completely as possible from the friction produced by the tension of the belt; for this friction will be combined with the resistance experienced by the belt, and will thus form part of the force recorded in the diagram, and be improperly charged to the machine under trial. Both the above requirements are met in this instrument by carrying each pulley in a bent bracket fixed to the end of the swing beam, Figs. 6 and 7, having a friction roller N on each side, against which the journals of the pulley bear. Such an arrangement however would be somewhat one-sided in supporting the pulleys, and some oblique deflection would be produced by the stress of the belt, causing the pulleys to be deflected from their true working plane so that the belt would run unevenly; and accordingly this was obviated by cranking the arms of the swing beam in the plane of the axes of the pulleys, as shown in the end elevation Fig. 5, so as to introduce a duly compensating deflection in a direction opposite to that in which the axes of the pulleys are deflected. By this means the object has been successfully accomplished, the axes of the pulleys being preserved truly parallel to the axis on which the swing beam vibrates.

In reference to the amount of stress brought upon the swing beam, it must be borne in mind that the working tension of the belt is composed of two distinct forces:—the fundamental tension of the belt whereby the requisite adhesion is maintained, which acts equally at both ends of the beam; and the excess of tension constituting the driving force, which acts solely at that end of the beam over which the tight side of the belt travels. The excess of tension or the driving force is wholly taken up by the springs of the indicating apparatus; and therefore the fundamental tension of the belt alone constitutes the stress upon the beam, which must accordingly be

strong enough to give sufficient adhesion for the greatest driving force that the dynamometer will have to measure. Now it appears by experiment, as will be shown in the further part of the paper, that when a belt is passed over a pulley with a weight suspended from each end, the arc of contact being a semicircle, the lighter weight must be at least one-third of the heavier in order that the belt may not slip; but practically it is better to reckon the lighter weight one half of the heavier, in order to be secure against the loss of power that would result from the belt slipping. The lighter weight is thus equal to the difference between the two weights; and as the lighter weight constitutes the fundamental tension of the belt, while the difference between the weights constitutes the driving force, the fundamental tension was taken to be equal to the driving force. The limit of driving force contemplated with the present instrument was 400 lbs., which was accordingly also taken as the fundamental tension; and since in the dynamometer each portion of the belt exerts its force twice on the pulley round which it passes, the swing beam was calculated to bear a load of 800 lbs. at each end when supported in the middle.

Considerable pains were taken at first to balance the swing beam accurately; and with this object the centre shaft on which it vibrates was fitted with an arm carrying an adjustable weight behind the swing beam, so as to counterbalance the preponderance of weight in front, which tended to keep the springs in a state of initial tension. But experience showed that it was better to augment rather than diminish this preponderance, and to add weight in front of the swing beam rather than behind it; for this secures a definite zero position of the swing beam and indicating springs, and is useful besides as a reserve of force to check the backlash which is liable to occur if the engine be inadvertently stopped too suddenly, since the momentum of the machine under trial is then arrested by reversing the tension on the belt.

The dynamometer at present constructed is so arranged that the tight side of the belt always runs upon the upper pulley C, and the indicating apparatus K is placed on a level with it; this arrangement accords with the direction of motion invariably adopted in the construction of thrashing machines. It was originally contemplated to adapt the instrument also to a motion in the reverse direction, the indicating apparatus being then brought opposite the lower pulley D; but it was considered that the greater complexity and cost of construction and the loss of time involved in shifting

the indicating apparatus would more than outweigh the inconvenience of working occasionally with a crossed belt.

It was hoped at first that if all the rapidly rotating parts were carefully balanced, sufficient steadiness of working would be secured without the intervention of the oil cylinder M; and with this view a suitable belt has been used, consisting of a double thickness of strong web, stitched together and saturated in boiled oil, combining remarkable suppleness, smoothness, tenacity, and adhesion. It was found necessary however to add the oil cylinder M; and notwithstanding these precautions the oscillation of the swing beam is still considerable, and indicates that in the force transmitted by a belt there exist inherent irregularities much greater than would have been anticipated from the nature of the work. The effects of obvious sources of irregularity are not however merged in those which were unexpected; and the momentary increase of force demanded by the irregularities in feeding the sheaves into a thrashing machine is rendered strikingly apparent in the progress of the diagram.

Specimens of the diagrams produced by the dynamometer are given in Figs. 8, 9, and 10, Plate 24, which show portions of the actual diagrams traced by the indicator pencil. The horizontal lines represent driving tensions of 50, 100, and 150 lbs.; the vertical lines mark intervals of 100 revolutions of the pulley on the swing beam. These diagrams were taken from machines tried at the exhibition of the West of England Agricultural Society at Cardiff in the present year. Fig. 8 is a diagram taken from a thrashing machine employed in thrashing wheat, the total mean tension throughout the whole trial being 110 lbs. Fig. 9 shows the power expended in thrashing barley, the total mean tension being 85 lbs.* Fig. 10 is from a chaff cutting machine, giving a total mean tension of 90 lbs.

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* The following are the particulars of the trials in which the diagrams shown in Figs. 8 and 9 were obtained :—

	Wheat.	Barley.
Number of sheaves thrashed	200	200
Mean tension of belt	110	85 lbs.
Total number of revolutions	7525	7050 revs.
Total length of belt passed	23639	22148 feet.
Total units of power consumed	2600290	1882580 ft.-lbs
Units of power consumed to thrash 1 sheaf	13001	9413 ft.-lbs.
Total time occupied in thrashing 200 sheaves	11·40	10·68 mins.
Horse power for driving thrashing machine in work	6·914	5·343 H. P.

(One unit of power is one pound weight raised one foot high.)

The motion of the recording cylinder K is transmitted from the upper pulley C on the swing beam through the two successive worm wheels R and S, Figs. 4 and 5, each of which reduces the speed $\frac{1}{50}$th, so that the rate of rotation of the recording cylinder is $\frac{1}{2500}$th of that of the pulley. In order however to avoid the errors which might creep into the analysis of the diagrams by constructing the longitudinal scale from the compound ratio of speed and diameter alone, the first worm wheel R carries a cam, which at each revolution acts upon a subsidiary pencil placed alongside the indicating pencil; as long as the subsidiary pencil is unmoved it traces a straight base line lengthways of the paper, but each action of the cam produces a momentary deviation, which forms a narrow indent on the base line, as shown in the diagrams, Figs. 8, 9, and 10, each indent marking the completion of 50 revolutions of the pulley C, or the travel of 157 feet of belt, the pulley having a circumference of 3·14 feet.

As in the analysis of the diagram each of these divisions marked by the cam stands for the unit of distance in calculating horse power, the calculation would be much simplified if the diameter of the pulley were made $\frac{5}{8}$ inch larger than 1 foot, giving a circumference of 3·3 feet, so that 10000 revolutions would be exactly 33000 feet, the measure of horse power. A few other improvements might also be made in minor points of detail in the construction of the dynamometer: the timber frame might be replaced with advantage by one of cast iron; and the indicating apparatus improved in detail, being in fact simply an adaptation of one that had been used previously for a somewhat different purpose, and this being the first dynamometer made on the construction now described. At present the time occupied in each experiment is noted by a watch; but the further addition of an apparatus for recording time on the diagrams would be a valuable improvement, and will probably be carried into effect; each diagram would then be complete in itself, all the data being self-recorded. It may also be noticed that the pulleys on the main shaft of the dynamometer, not having been turned true throughout, have a slightly eccentric centre of gravity; and running frequently at a speed of 600 or 700 revolutions per minute they create an unpleasant and probably objectionable tremor: they will therefore be put thoroughly in balance before the dynamometer is used again.

The scale of tension in the diagrams obtained with the dynamometer is determined as follows. The working belt is removed, and replaced by a

belt attached at one end to a fixed point O in the foot of the frame, as shown dotted in Fig. 1, and passing over the power supplying pulley A (which now serves merely as a guide pulley), then round the upper pulley C on the swing beam, and over the large guide pulley G. The loose end of the belt is provided with a dish to hold the weights used in determining the scale. Any weight suspended at the extremity of the belt will now give exactly that stress on the indicating springs which would be produced by an effective driving force of the same amount. The dish with its appendages makes up a weight of 50 lbs.; and therefore brings the indicating pencil to the same position that it would have if a machine were under trial with an effective driving force of 50 lbs.; a small motion now given to the paper cylinder by hand marks on the paper the position of the pencil. The same operation is repeated with such successive increments of weight as serve to make up a convenient fundamental scale; and whatever irregularity there may be in the springs themselves, or whatever want of equilibrium in the swing beam, the scale thus constructed is accurate, since it is made by the identical forces which it will have to record and measure. In order that this scale of tension may appear throughout the entire length of each diagram, eight adjustable pencils carried in a frame rest upon the paper just clear of the path of the indicating pencil, each of which is adjusted accurately to one of the lines marked in the formation of the scale; as the diagram proceeds, each pencil rules a straight line on the paper, showing the position due to the force which it represents. This greatly facilitates the analysis of the diagram, and adds to the accuracy of the results; and a further facility might be obtained by using pencils of distinctive colours, so that for example each 100 lb. line should be red, and each 50 lb. line blue.

Friction Dynamometer.—The second kind of Dynamometer, forming the further subject of the present paper, is adapted for the power supplying class of machines; and, like the other instruments constructed for this purpose, it acts upon the principle of absorbing by a friction break the power given out by an engine when working at regular speed and pressure, and measuring the weight required to give the necessary amount of friction to absorb the whole power. The simple form of break first used for this purpose has undergone considerable modifications: for an instrument is required which can be maintained in continued action for a long period

without any variation in the resistance which it offers to the motion of the engine; so that the total power developed in each case may be accurately ascertained, without any correction being required for variation in the resistance overcome during the period of trial.

In order that the description and principle of this new break dynamometer, which is the invention of Mr. John Imray of Lambeth, may be rendered clear, some examination is required of the action of belts and the principles that regulate their friction.

The friction or hold of a belt upon a drum is independent of the diameter of the drum: for although it has been sometimes considered that a belt of given width drives a drum of large diameter with less slip than one of smaller diameter, and this may be the case if the belt be rather rigid, and the comparison be made between a large drum round which the belt can easily bend and one so small in diameter that the resistance of the belt to flexure prevents it from bearing fully on the surface of the drum; yet within fair limits and with belts of sufficient flexibility it will be found practically that the diameter of the drum has no effect whatever on the friction of the belt upon its surface. This has been experimentally proved by Mr. Imray with drums of various sizes ranging from $5\frac{1}{2}$ inches up to 14 inches diameter, and from $15\frac{3}{4}$ inches up to $38\frac{3}{4}$ inches diameter, in the following manner. The drum was held fast in its bearings, and a belt passed over it so as to embrace half the circumference, with weights P and W hung from its extremities. The larger weight W was gradually increased until it just made the belt slip; and consequently the excess of W over P exactly measured the friction of the belt. The ratio of W to P was thus determined; and it is evident that if with a given arc of contact this ratio be found to remain invariable, whatever be the diameter of the drum, then the friction also is independent of the diameter. It may be remarked that considerable difficulty was experienced in ascertaining the precise weight which caused the belt to slip; for the last pound added to cause motion might be removed again without arresting the slip when once the motion had begun: and especially in the cases where the weights were considerable, and consequently the inertia to be overcome great, the difference of weight necessary to occasion slip was found to be greater by several pounds than that necessary to maintain the slip when once begun.

In the first set of experiments that were made in this manner five drums were used of small diameter, ranging from $5\frac{1}{2}$ inches to 14 inches;

and were selected because they had very nearly equal convexity on the rim, the convexity being in each case about $\frac{1}{8}$ inch in a breadth of 2 inches, and because their surfaces were equally smooth and polished. The same belt was employed with each drum; it was old and oily and very flexible, $1\frac{5}{8}$ inch broad and $\frac{1}{8}$ inch thick, weighing about 2 lbs.; and in reckoning the values of P and W half the weight of the belt or 1 lb. was added to each of the actual weights suspended. The following results were obtained, showing the values of the ratio of W to P with the different diameters of drum:—

TABLE I.

Experiments on Friction of Belts on Drums (small diameter).
Arc of Contact 180°.

Number of Experiment.	Diameter of Drum.	Weight of P.	Weight of W.	Value of Ratio $\frac{W}{P}$.	Mean Value of Ratio $\frac{W}{P}$.
	Inches.	Lbs.	Lbs.		
1	5·5	18	29	1·611	1·675
2		34	57	1·676	
3		65	113	1·738	
4	7·6	17	29	1·706	1·733
5		32	57	1·781	
6		66	113	1·712	
7	9·8	17	29	1·706	1·733
8		32	57	1·781	
9		66	113	1·712	
10	11·8	18	29	1·611	1·642
11		34	57	1·676	
12		69	113	1·638	
13	14·0	17	29	1·706	1·673
14		34	57	1·676	
15		69	113	1·638	
				Average value of Ratio $\frac{W}{P}$ =	1·691

From these experiments it appears that the largest drum presented almost exactly the same friction as the smallest; and the results of all these fifteen experiments agree so nearly that it may safely be inferred that the diameter does not affect the amount of friction.

In the second set of experiments three drums were tried of the diameters 15·8 inches, 24·0 inches, and 38·8 inches respectively. The largest drum was well polished and greasy; the smallest was turned but not polished, showing the tool marks; and the intermediate size was also turned, but not quite so smooth as the smallest. In these experiments

also the belt was old and oily and tolerably flexible, about 3 inches broad and $\frac{3}{16}$ inch thick; and the weight of the belt and scales for receiving the weights being 28 lbs., half that amount or 14 lbs. was added to each value of P and W. The following were the values of the ratio of W to P with the different diameters of drum :—

TABLE II.

Experiments on Friction of Belts on Drums (large diameter).
Arc of Contact 180°.

Number of Experiment.	Diameter of Drum.	Weight of P.	Weight of W.	Value of Ratio $\frac{W}{P}$.	Mean Value of Ratio $\frac{W}{P}$.
	Inches.	Lbs.	Lbs.		
16	15·8	14	37	2·643	2·697
17		42	107	2·548	
18		70	203	2·900	
19	24·0	14	35	2·500	2·322
20		21	49	2·333	
21		42	91	2·167	
22		70	160	2·286	
23	38·8	14	42	3·000	3·129
24		16	49	3·063	
25		20·5	60	2·927	
26		28	94	3·357	
27		41	126	3·073	
28		70	235	3·357	
Average Value of Ratio $\frac{W}{P}$ = 2·716					

From these experiments it appears that while the largest of the three drums presented the greatest friction, yet the smallest presented more than the intermediate size, and the discrepancy is readily accounted for by the difference in the smoothness or polish of the surfaces. In neither set of experiments does the result with any of the drums differ from the average more than may fairly be accounted for by variations in the polish of the surface.

That the friction of a belt is thus independent of the diameter of the drum which it embraces is the result arrived at also by theory. The formula obtained by theory for the ratio of W to P is

$$\text{hyp. log } \frac{W}{P} = f \times a;$$

$$\text{or } \frac{W}{P} = 2{\cdot}72^{f \times a};$$

2·72 being the base of the hyperbolic logarithms, f the coefficient of friction or the ratio of the friction to the pressure, and a the angle of the arc of contact of the belt with the drum.* This formula does not involve the diameter of the drum, and accordingly shows that the friction is independent of the diameter. And it may be remarked that although it is matter of common observation that, when a belt is overloaded with work and slips on the drum, the slip is prevented by substituting a drum of larger diameter; still this effect does not result from an increase of friction being obtained with the larger drum, but simply from the circumstance that the velocity of the circumference of the larger drum being greater at the same number of revolutions per minute, the friction required to transmit the same amount of horse power is proportionately less, and accordingly falls below the limit at which the belt begins to slip.

The above formula is represented in the form of a curve in Fig. 18, Plate 26, by means of which the value of the ratio of W to P may be readily found for any values of the coefficient of friction and arc of contact. Thus if the coefficient of friction f be $\frac{1}{3}$ or 0·33, and the arc of contact a be 2, that is twice the radius, as in Fig. 17, then the product $f \times a$ is 0·67; and finding this point on the base line in Fig. 18, the corresponding height is 1·95, which is therefore the value of the ratio $\frac{W}{P}$.

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* This formula is arrived at as follows:—

Let t be the tension of the belt at any point T intermediate between R and S, Fig. 17, Plate 26; and A the angle of the arc of contact RT, that is the angle RCT. Also let $t + dt$ be the tension at the next point U nearer to S, at which the angle of the arc of contact is $A + dA$. Now it is evident that the additional tension dt at the point U must be equal to the friction of the belt over the arc TU, that is to $f \times p$ f being the coefficient of friction and p the pressure of the belt on the arc TU.

$$\text{Therefore } dt = f \times p.$$

Now the relation between the tension and the pressure at all points of the arc of contact is $p = 2 \times t \times \sin \frac{dA}{2}$; therefore $p = t \times dA$, since $\sin \frac{dA}{2} = \frac{dA}{2}$ because $\frac{dA}{2}$ is an infinitely small angle.

$$\text{Therefore } dt = f \times t \times dA,$$

$$\text{or } \frac{dt}{t} = f \times dA.$$

Hence integrating and observing that when $A = o$, $t = P$, and when $A = a$, $t = W$,

$$\text{hyp. log } \frac{W}{P} = f \times a;$$

$$\text{or } \frac{W}{P} = e^{f \times a} = 2{\cdot}72^{f \times a}.$$

In order to check the formula above given by the results of actual trial, in regard to the relation obtaining between the friction and the arc of contact, a third series of experiments was tried, with the same three drums that were used in the second series. The drums were held fast in their bearings as before, and an adjustable roller was introduced between the belt and the circumference of the drum, as in Fig. 17, Plate 26, so as to vary the extent of circumference embraced by the belt. The number of degrees in the arc of contact RS was approximately estimated; but it was difficult to ascertain accurately the extent of the arc of contact, since the points R and S where the belt appears to leave the circumference of the drum are by no means definitely marked. The following values of the ratio of W to P were obtained in the experiments, and the values arrived at by theory by the formula already stated * are also given :—

TABLE III.

Experiments on Friction of Belts on Drums (large diameter). Arc of Contact Variable.

Number of Experiment.	Diameter of Drum.	Arc of Contact.	Weight of P.	Weight of W.	Value of Ratio $\frac{W}{P}$.	Mean Value of Ratio $\frac{W}{P}$.	Theoretical Value of Ratio $\frac{W}{P}$.	Error per cent.
	Inches.	Degrees.	Lbs.	Lbs.				
29			14	25	1·786			
30	15·8	120°	42	84	2·000	1·962	1·938	$1\frac{1}{4}$
31			70	147	2·100			
32			14	24	1·714			
33	24 0	123°	42	78	1 857	1·809	1·778	$1\frac{3}{4}$
34			70	130	1·857			
35			14	34	2·429			
36			16	39	2·437			
37			21	52	2·476			
38	38·8	144°	28	70	2·500	2·506	2·491	$\frac{1}{2}$
39			42	109	2·595			
40			70	182	2·600			

* The following is the method by which the theoretical value in Table III. is calculated in the case of the first drum, of 15·8 inches diameter; and the same method applies in the two other cases. The result might also be obtained roughly from Fig. 18.

From Table II. it appears that with the drum 15·8 inches diameter, when the arc of contact is 180°, $\frac{W}{P} = 2.697$; therefore hyp. $\log \frac{W}{P}$ = hyp. log 2·697 = 0·992. And by the formula hyp. $\log \frac{W}{P} = f \times a$; hence $f \times a = 0{\cdot}992$, when a is an angle containing 180°. Therefore $f \times a = 0{\cdot}992 \times \frac{120}{180} = 0{\cdot}661$, when a is an angle

On comparing the results of the experiments with those deduced from theory, it appears that with the smallest drum, with an arc of contact of 120°, the mean value of the friction was 1·962, while by theory it is 1·938, making only $1\frac{1}{4}$ per cent. error. Again, with the intermediate sized drum, with an arc of contact of 123°, the mean value of the friction was 1·809, while by theory it is 1·778, giving an error of $1\frac{3}{4}$ per cent. And with the largest drum, with an arc of contact of 144°, the mean value of the friction was 2·506, while that given by theory is 2·491, showing an error of only $\frac{1}{2}$ per cent. In the instance of the smallest drum, if the angle of contact were taken as between 122° and 123°, instead of 120°, the result by the formula would precisely accord with that of the experiment; and such an error might readily occur in observing the angle of contact, since it was impossible to ascertain its extent correctly within even 5°.

These experiments accordingly fully confirm the results arrived at by theory in reference to the relation of the friction to the arc of contact; and this relation may be illustrated by the fact that the friction obtained by 2 turns of a rope round a post, whatever be its diameter, is the square of that obtained by a single turn, while 3 turns raise it to the cube, and so on. Thus a single turn of a hemp rope round an oak post gives a value of say 9 very nearly for the friction; or in other words a tension of 1 lb. applied at one end of the rope will resist a tension of 9 lbs. at the other; two turns then give a friction of 9×9 or 81; three turns a friction of $9 \times 9 \times 9$ or 729; and so on, every additional coil thus giving an enormous increase of friction.

It was seen by Mr. Imray that the results of the above experiments might be applied to the construction of an accurate instrument for the measurement of power by means of a friction break or dynamometer. In the previous instruments of this kind, the total friction of the belt on the drum, after having been originally adjusted in amount by the weights suspended from the belt, is then regulated to maintain the instrument in

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containing 120°. Therefore as before by the formula hyp. log $\frac{W}{P} = f \times a = 0{\cdot}661$, when the arc of contact is 120°. Now 0·661 = hyp. log 1·938; hence hyp. log $\frac{W}{P}$ = hyp. log 1·938. Therefore $\frac{W}{P}$ = 1·938, which is the theoretical value, as given in the paper. (In this case the value of f is 0·316 as deduced from the above value of $f \times a = 0{\cdot}992$.)

its correct adjustment: this is accomplished either by means of a tightening screw in the belt adjusted continuously by hand, as in the earlier dynamometer; or by means of a lever with unequal arms, as in Mr. Appold's and Mr. Balk's ingenious friction breaks, so arranged that within the required limits the tightness of the belt shall adjust itself, any diminution in the intensity of the friction being corrected by the self-acting tightening of the belt, and *vice versâ*. The general principle of these two self-adjusting friction breaks is illustrated by the diagrams, Figs. 15 and 16, Plate 26, respectively.

It was considered by Mr. Imray that, by taking advantage of the principle that the friction varies with the extent of the arc of contact, an instrument might be devised capable of adjusting itself perfectly to the work and not requiring any variation in the tightness or pressure of the belt, however great might be the variation in its state of lubrication or dryness and the consequent intensity of the friction. The break dynamometer by which this principle is carried into practice is shown in Figs. 11 and 12, Plate 25; Fig. 11 being a side elevation, and Fig. 12 a plan. The friction drum A is fixed on the shaft B driven by the engine or other power supplying machine to which the dynamometer is applied for the purpose of measuring the power developed. Two radial arms CC are fitted one on each side of the drum A, having their extremities DD formed to coincide accurately with an arc of the circumference of the drum; the arms are capable of revolving freely on the shaft B, and their other extremities are connected together by a weighted tie bolt E, by means of which they are carefully balanced upon the shaft. The friction belt is attached by a pin at one end F to the radial arms C, and at the other end is suspended the counterbalance weight P keeping the belt in close contact with the drum over the arc EF. The load W is suspended from the extremities D of the radial arms by means of two thin brass straps or chains passing over the arcs D, on each side of the drum and not in contact with its circumference.

The action of the dynamometer is as follows :—while at rest, the load W remains on the ground as in Fig. 13, Plate 26; but on putting the drum in rotation in the direction of the arrow, the friction belt being strained tight by the counterbalance weight P and being in contact with the drum over the arc EF presents sufficient friction to raise the load W and with it the radial arms C, which continue to rise and by their rise to

diminish the arc of contact of the friction belt and reduce the amount of friction until they assume such a position, as in Fig. 11, that the counterbalance weight P and the friction of the portion of the belt in contact with the drum just balance the load W. Whenever the intensity of the friction is increased during the trial beyond the average, from heating or imperfect lubrication, the arms C will rise still further towards the extreme position shown in Fig. 14, Plate 26, and thereby further diminish the arc ofcontact EF; and whenever the intensity of the friction is diminished, as by the use of oil, the arms will fall back and increase the arc of contact EF until the friction will sustain the load: the total friction being thus preserved constant. The load W and counterbalance weight P are adjusted beforehand within proper limits, so that the vibrations of the arms C may be confined within the extreme positions shown in Figs. 13 and 14.

In this break dynamometer accordingly the load remains constant during the whole trial, and acts at a constant leverage by means of the arc D at the end of the arms C; while at the same time the total friction of the belt on the drum also remains invariable, being entirely unaffected by changes in the coefficient of friction, since a corresponding correction instantly takes place in the length of the arc of contact of the belt. Hence in applying this dynamometer to measure the power of an engine it is only necessary to take the difference in lbs. between the load W and counterbalance weight P, and multiply it by the velocity of the circumference of the friction drum in feet per minute; the product of these divided by 33000 gives the horse power developed by the engine. In the dynamometer which has been made on this plan the drum was turned to exactly $16\frac{1}{2}$ feet in circumference, or about 5 feet 3 inches diameter, and a counter was attached to indicate the number of revolutions per minute. If this number be represented by n, the velocity of the circumference of the drum will be $16\frac{1}{2} \times n$ feet per minute, and the horse power will be $\frac{(W-P) \times 16\frac{1}{2} \times n}{33000}$. Thus in one instance the load W was 170 lbs. and the counterbalance weight P was 10 lbs., the difference W – P being therefore 160 lbs.; and the number of revolutions per minute being 124, the power given out by the engine was accordingly 9·92 horse power.

In some of the first experiments made with this break dynamometer, the friction belt being of woollen girth faced with canvas and served with a paste of black lead and tallow, the radial arms vibrated somewhat more than was considered advisable, especially when oil was applied to the drum;

hat is to say, when any variation occurred in the intensity of the friction, the belt in adjusting itself suddenly to its new position, and thereby putting the suspended weights in motion, was apt to overrun itself and cause the radial arms to oscillate above and below their proper position. In order to avoid this apparent objection, which though it did not affect the accuracy of the test might yet seem objectionable to those whose engines were subjected to it, the counterbalance weight P was arranged in the form of a piston and rod immersed in a cylinder containing water; the piston fitting the cylinder so loosely that it could gradually assume the true position of equilibrium, while at the same time its movement was so much resisted by the water that it could not undergo sudden changes of position. This arrangement rendered the dynamometer as steady in its action as could be desired; and moreover afforded the means of eliminating a small error previously existing in the principle of the apparatus. On referring to Figs. 13 and 14, Plate 26, it will be seen that while in Fig. 13 the length of belt EP suspending the counterbalance weight P is short, in Fig. 14 it is considerably lengthened by the amount of belt unwound from the drum. Since the belt is of some weight in itself and since every inch added to EP involves also an inch taken from the other end, the relative values of W and P were altered with every alteration of the arms by twice the weight of belt wound on or unwound from the drum; and although the error thus resulting would be very inconsiderable, yet it was considered desirable to get rid of it entirely. For this purpose the rod by which the piston P was suspended in the water was made of wood, of such a sectional area that every inch of its length immersed in water should displace a weight of water exactly equal to twice the weight of one inch length of belt; thus the increased floatation given by the increased immersion of the rod exactly compensated for the variation in the relative weights of W and P.

In employing this instrument with the belt described above, it was found that the friction varied to a certain extent with the velocity; or that between the surfaces of the drum and belt there existed some adhesive force, which, for want of a better name and a proper explanation of its nature, has been called *suction*. The drum in revolving tends to drag the belt with it, and the faster it revolves the greater is this tendency; producing the same effect as if the intensity of the friction were increased. When the belt is faced with wood however this effect is not produced; for whatever be the speed, the friction as measured by the ratio of the weights W and P

remains uniform in this case. And further, with the belt alone the friction very much exceeds that of the wood facing; so that the friction obtained with a belt over a small arc of contact is as great as that obtained with wood over a considerable arc. It is accordingly proposed to face the belt with wood over a portion of its length FG, as shown in Fig. 11, the belt itself remaining in contact with the drum over only a small arc EG. For it appears from the formula that for any change in the intensity of the friction the length of the arc of contact must vary inversely as the coefficient of friction; thus if the coefficient of friction be diminished in any ratio, the length of the arc of contact must be increased in the same ratio: therefore the absolute increase of length of the arc, or the extent of vibration of the radial arms, will be exactly proportional to the total length of the arc of contact; so that, for example, with a given alteration in the intensity of the friction, the vibration of the arms when the belt is in contact with the drum over the arc EG will be exactly half of the vibration that would take place if the arc of contact were twice the length. The arrangement shown in Fig. 11 will consequently improve the steadiness of the radial arms, and thereby permit a much greater range for variations of intensity of the friction within the limits of the arc through which the arms can vibrate.

Mr. Henry Maudslay observed that the paper just read was a very valuable one, and both scientific and practical in its nature. The great necessity for employing a dynamometer was not sufficiently perceived at first by employers, but he might mention a striking instance with which he had been connected at the Great Exhibition in 1851, where among the machines for raising water were three centrifugal pumps, in one of which the work done in raising water appeared but small, while the others appeared to be discharging a large quantity; whereas the actual results ascertained by Morin's dynamometer were that the latter gave a much inferior percentage of duty, the greatest portion of the power being spent in churning the water without useful effect. In the same manner some thrashing machines might seem to be doing a great amount of work, while others working more quietly and apparently doing less might be really superior in duty performed with the same power.

Hence it was very desirable that dynamometers should be employed for testing the actual work done, and they had hitherto not been used so much as they should be, from not being sufficiently known and appreciated; their further introduction would certainly result in a saving of useless resistances and economy of power. The dynamometer constructed by Col. Morin, that was used in the trials by the Jury of the mechanical section at the Exhibition of 1851, was a very excellent instrument, and he should be glad to have an explanation as to the essential difference between that and the belt dynamometer described in the paper.

Mr. W. Froude said he was not aware of Morin's dynamometer when he constructed his own, or would not have undertaken the construction of an instrument to perform a duty so well performed by one already in existence. He had not seen the instrument itself, but the principle consisted in having a loose pulley on one end of a shaft driven by the engine, connected to the shaft by a spring apparatus to measure the driving force in a manner similar to that in which the main spring of a watch might be said to measure by its tension the force transmitted by the arbor to the barrel, so that the driving power of the shaft passed through this spring, causing a varying deflection according to the fluctuations in the power. A very beautiful integrating apparatus was added, which was more perfect than his own, as it added up the result continuously, so as to show on a dial the total sum of the power supplied. But he believed that the dynamometer described in the paper must be more delicate in recording the fluctuations of power, since the resistance opposed to any change in position of the swing beam was so slight, and the indications were consequently remarkably delicate; the slightest fluctuation in the power consumed by the machine under trial being plainly shown in the diagram.

The instrument was first tried without an oil cylinder; but the oscillations then extended occasionally to 20 or 30 lbs., and there was a disagreeable backlash when the machine under trial was empty. It therefore became necessary to apply the oil cylinder, which offered no permanent obstruction to a slow motion of the swing beam, but checked only sudden jerks. This was theoretically open to objection, for if the passage for the oil were not equally free in both directions, the piston might be retained in a permanently false position. Experience however showed that such an error if it existed was so small as to be practically unimportant; for when a machine of uniform load was under trial it was found that very great variations in the

freedom of passage allowed to the oil and in the range of casual oscillations produced no sensible change in the position of the mean line. These variations were managed by varying the aperture of a cock placed in a pipe connecting the two ends of the cylinder; for it had been thought prudent to retain this power of regulating the oscillations: this however was now abandoned, and in the present diagrams much more oscillation was allowed than in those first taken. The movements of the swing beam corresponded strikingly with the momentary efforts demanded by the successive sheaves as they were fed into the machines under trial; and, seeming to bear witness to the veracity of the resulting diagram, contributed not a little to the feeling of satisfaction experienced by the makers of the machines.

The trials of the competing machines were very closely contested, a given number of sheaves being supplied to each machine, sufficient to occupy about 15 minutes in thrashing. The trial of each machine was commenced by running it empty for a few minutes, partly as a test of its constant resistances, partly to see all clear for the working trial. The large proportion of power demanded by the machines thus running empty, seldom less than half and often three fourths of the working duty, caused much surprise to the makers, and usefully drew their attention to its sources, the winnowing fan and the reciprocating action of the straw shakers. The power thus absorbed was shown in the first portion of the line in the diagram Fig. 8. A comparison of the working portions of these two diagrams showed the difference between the power consumed in thrashing wheat and thrashing barley, due to the greater stiffness and bulk of the wheat straw.

It should be explained that the present dynamometer had been hastily constructed to be ready for work on a certain day of trial, and the wood frame was consequently adopted as the quickest made; several improvements in details of construction might be made with advantage in future instruments. The dynamometer had been used by the West of England Agricultural Society to test the machines submitted for trial at their two last exhibitions.

The Chairman asked what were the advantages of the friction break described in the paper as compared with other self-adjusting breaks.

Mr. W. Froude replied that the two forms of friction break previously used involved a small fundamental source of error, arising from the intro-

duction of the differential lever to effect the self-adjustment. Thus in Mr. Balk's friction break, the self-adjusting power was obtained by varying the tension of the belt by the action of the unequal arms of the lever: any increase of friction raised the load above the original position, causing the long arm of the lever to give out more belt than was taken up by the short arm, so that the belt was slightly slackened. If carried to a sufficient extent, the belt would be entirely released from the break wheel; but in actual work the result was simply that the elastic tension was reduced. Now supposing the long arm of the lever were $\frac{1}{32}$nd part longer than the short arm, the tension at the short end would be $\frac{1}{32}$nd part greater than at the other, and this was allowed for in the original adjustment of the apparatus suitably to the mean position of the lever; but if the coefficient of friction varied, this original adjustment became incorrect, since the alteration of tension produced at the short end of the lever was $\frac{1}{32}$nd greater than the alteration of tension at the long end, instead of being exactly equal at both ends. A small error was thus produced in the amount of the effective load sustained; and a similar error existed also in Mr. Appold's break, the self-adjusting action of the lever here also involving a slight variation in the relative tensions produced by it on the opposite ends of the belt, and consequently in the effective load. The error however was in both cases so small in absolute amount that it would be unnecessary to notice it, but that the effect of any error must accumulate during the period of each trial; and it seemed therefore desirable if practicable to make a theoretically perfect dynamometer, as the instrument had become so important for measuring the power of competing machines.

The friction break constructed by Mr. Imray was placed upon wheels, as shown in the drawing, running on a temporary railway under a shed for convenience of application, so that one engine could be brought up and fixed ready for trial while another was being tried; the shaft of the break wheel was carried on friction rollers, to reduce the friction of the bearings. He wished to remark that the latter part of the paper, giving the description of the friction break and the experiments on the friction of belts, had been prepared by Mr. Imray.

Mr. C. W. Siemens observed that in any dynamometer the first consideration was whether any error existed in the principle, and then whether the error was of any importance or could be determined. He was inclined to think that some source of error was involved in the use of the

oil cylinder in the belt dynamometer that had been described, on account of its yielding differently to a gradual movement and to a sudden jerk. If a jerk were equally sudden in both directions, no error could ensue; but if the movement were gradual in one direction and abrupt in the other, the piston would be permanently displaced from its correct position, and the area of the diagram would be made fuller by this circumstance than it should be, or the contrary. Also since the friction of the pulleys on the swing beam, however much reduced by friction wheels, would still form a portion of the work done, he thought it would be desirable to ascertain the exact amount of the error thereby produced and introduce the actual correction in the results.

Mr. W. Froude admitted that the use of an oil cylinder certainly involved in principle the error referred to; but after a careful examination of its action he had come to the conclusion that in practice the disturbances were so nearly equal in the two directions that the amount of error was inappreciable. The decisive test of this would be to try whether a spring balance provided with an oil cylinder and loaded with say 56 lbs. would continue to indicate correctly the weight supported, if it were suspended from the axle of a carriage jolting over a rough road. He had not tried this experiment; but in the first use of the dynamometer, when the oil passage was provided with a cock, he had varied the conditions by changing the degree of throttling and reversing the cock; and while the load on the dynamometer remained unchanged no perceptible variation was produced in the mean line of the diagram. A case might of course be supposed where the greater ease of passage in one direction would make a perceptible difference, as where the opening had the form of the vena contracta in one direction with a sudden contraction in the other; but he believed in the oil cylinder as at present used the error was inappreciable.

The friction of the pulleys on the swing beam must be very small in amount, since the journals of the pulleys were only 1 inch diameter running on the circumference of 9 inch friction wheels; and though the resistance, whatever it might be, became certainly charged to the machine under trial, he thought it could not appreciably affect the result. It had often occurred to him in reference to the agricultural machines that the use of friction wheels might with great advantage be adopted for the bearings of the main driving shafts, as in thrashing machines, where there was frequently a great loss of power, many machines being driven by a 5 inch pulley on

a $1\frac{1}{2}$ inch shaft, the diameter of the pulley being much too small for so large a shaft. There was no doubt that some part of the loss of power shown in the diagram in driving the machines empty arose from this cause; this loss of power amounted to 50 lbs. tension when empty out of 110 lbs. total tension when thrashing wheat, or out of 85 lbs. with barley, as shown on the diagrams, being a proportion of 45 or 59 per cent. respectively of the total power in the two cases.

The CHAIRMAN enquired whether any difference was produced in the working of Mr. Imray's break by the use of oil. In Mr. Appold's break used in the Atlantic telegraph apparatus it did not matter whether the break wheel were running in water or dry, or whether oiled or not; the tightness of the belt being instantly self-adjusted by the action of the differential lever, which was certainly very beautiful and instantaneous in its operation.

Mr. W. FROUDE replied that within the range of self-adjustment contemplated in its construction Mr. Imray's break retained the identity of its working load whether dry or lubricated, adapting itself instantly to any variation in the coefficient of friction by a corresponding variation in the length of the arc of contact of the belt with the break wheel, and it was theoretically perfect in that respect. The only disturbance occurring in practice arose from the adhesion or stickiness of the belt that had been referred to in the paper, which created an uncorrected irregularity at first starting when the motion was very slow; thus whereas while the instrument was fairly in motion a counterbalance weight of 5 lbs. would support a load of 120 lbs. under great variations of speed and lubrication, it required at starting a counterbalance of 15 lbs. to support the 120 lbs.: by the use of the wood facing however over the greater portion of the belt, as described in the paper, this difficulty was entirely got rid of.

A useful application that had occurred to him of the belt dynamometer described in the paper might be readily made in a workshop by setting up a simple apparatus for testing the power used in driving a lathe or any other tool.

Mr. R. BACH observed that he had used the common friction dynamometer for testing a great many engines, and had always found it satisfactory in action; it had been used also at the recent meeting of the Royal Agricultural Society at Chester, for testing all the engines exhibited there. It had the advantage of great simplicity and economy of construc-

tion, consisting only of a break wheel 5 feet diameter, with eight blocks of wood round the circumference, tightened by a hand screw in the belt, and loaded by a weight suspended from one side. He had seen this break kept working continuously for 20 minutes without touching the adjusting screw by hand, with only about 3 inches play in the height of the weight during that time; and had tested engines with it up to 20 horse power at 110 revolutions per minute. This break also admitted of being applied direct to the flywheel of an engine without requiring any separate machine.

He showed a drawing of a new apparatus proposed for measuring the power transmitted from an engine through a shaft to any machine by means of three bevil wheels, one on the end of the driving shaft and another on the driven shaft, with the third or intermediate wheel at right angles to the two others, running loose on the end of a lever, the other end of which was attached to a spring balance and indicating apparatus; the deflection of the lever or the extension of the spring balance thus showed the amount of power transmitted through the teeth of the intermediate bevil wheel.

Mr. C. W. Siemens said he had made trial of a similar plan some years ago, and found it answered well as an indication of the power transmitted, but it had rather too much oscillation.

Mr. W. Froude said there was no objection to the common dynamometer or friction break for any one testing his own engines; but in public trials closely contested by many competitors it was highly desirable that the dynamometer should be completely self-adjusting, so as to continue working correctly without being touched by hand during the whole period of trial, in order that the owners of engines under trial might have full confidence in the results, from the knowledge that the instrument was entirely beyond control or tampering with.

The Chairman had employed the form of the ordinary friction break with a horizontal loaded lever working between two stops, known as Tredgold's dynamometer; and he had seen it continue working satisfactorily for an hour together without requiring readjustment.

Mr. W. Froude observed that the instrument first used by the West of England Agricultural Society in their trials had been one of the ordinary friction breaks; but though it was nicely constructed its irregularity of action had been great, requiring frequent adjustment of the tightness of the belt by hand; and its use had been abandoned on account of the objection felt to any handling of the instrument during the progress of the trials.

Mr. R. Bach thought there was an objection to using an instrument separate from the engine to measure the power of the engine, as that required a driving belt and caused the flywheel shaft to be strained in its bearings during the trial, increasing the friction of the shaft. It was better to apply the friction break direct to the engine, by placing the friction belt and blocks of the common dynamometer round the flywheel of the engine; the friction of the bearings would then be much less.

Mr. W. Froude remarked that in practice the engine would have to work with a belt in driving machines, involving the extra friction on the journals due to the tension of the belt; and therefore the use of a driving belt and separate testing machine had really the effect of placing the engine more nearly in the condition of actual working.

The Chairman thought the paper that had been read was a very valuable one, combining mathematical investigation with practical experience, and was glad the subject had been so fully taken up in it; he thought there could not be too many dynamometers, as they were of so much importance. He proposed a vote of thanks to Mr. Froude for the paper, which was passed.

The following Paper, by Mr. Charles Beyer, of Manchester, was then read:—

DESCRIPTION OF WATERHOUSE'S COMPRESSED AIR FORGE HAMMER.

This forge hammer, which is the invention of Mr. Thomas Waterhouse of Sheffield, is intended for general light work in a smith's shop, such as forgings ranging from 1 to 5 inches diameter; it is driven by a strap, as in the various kinds of friction hammers, but has combined with it a compressed air cylinder, the air in which acts as an elastic spring, which can be controlled so exactly by means of inlet and outlet valves and an adjustable head piston as to regulate completely the force and rapidity of the blow of the hammer, giving some important advantages in its efficiency and general utility.

The steam and friction hammers in general use, excepting the tilt hammers working with a spring or striking beam, are limited in their speed by the time required for the hammer to fall at each stroke; and do not admit generally of being worked at a quicker speed than about 80 blows per minute. But this speed is quite inadequate for light smithy purposes; and in the hammer now described the elastic action of the compressed air in the cylinder increases the velocity of the fall of the hammer so much as to allow of 120 to 150 blows per minute being readily obtained, the working of the hammer being usually limited to 130 blows per minute, which are as many as can be ordinarily dealt with by a smith.

The present improved form of this compressed air hammer is shown in Plates 27, 28, and 29; Fig. 1, Plate 27, is an elevation of the complete machine; Fig. 2, Plate 28, is a vertical section, and Fig. 3 a sectional plan. Figs. 5, 6, and 7, Plate 29, show an enlarged vertical section and plans of the air cylinder.

The hammer block A, Figs. 1 and 2, works between guides in the frame, as in Nasmyth's steam hammer, and is lifted by the rod B, which is made double and flat, with a roller C fixed in the middle projecting a little backwards from the centre line. This roller is lifted by the cam D, as shown enlarged in Fig. 4, Plate 28, which is forged solid upon the horizontal shaft E, and works between the two halves of the hammer rod,

being hardened on the face. The shaft E is carried by bearings in the framing at each end, and passes close behind the hammer rod B; it has fast and loose pulleys F upon one end, and a small flywheel G upon the other. The hammer is driven by a strap on to the pulley F, each revolution of the cam making one stroke of the hammer.

On the top of the frame is the air cylinder H, open at the bottom, in which works the piston I forged upon the hammer rod B. The air in this cylinder is compressed by the piston I each time the hammer is raised by the cam; and its elastic force in expanding again increases the velocity of the hammer in falling, giving a great increase to the force of blow when required, and to the number of blows that can be struck per minute. The elastic force of the compressed air is regulated by altering the quantity of air that is compressed by means of a second stationary piston K, the height of which can be adjusted in the cylinder by a hand wheel and screw passing through the cylinder cover; by lowering this piston the space into which the air is compressed between the two pistons is reduced, and the pressure of the air proportionately increased, so as to increase the force of blow.

A cock L, Figs. 5 and 7, is fixed in the side of the air cylinder between the two pistons, by opening which the air is allowed to escape instead of being compressed; and by adjusting the opening of this cock the pressure can be reduced to any amount required, so as to vary the force of blow at any moment as desired during the working of the hammer. A valve M is placed in the upper piston K, consisting of a circular flap opening downwards and kept close by a light spring, for the purpose of admitting air between the two pistons, in order to prevent a partial vacuum being formed between them, which would retard the fall of the hammer. As the cock L remains open during the fall of the hammer, a portion of the air will re-enter there; but this entering only at the pressure of the atmosphere will be much less than the quantity escaping through the same aperture under the compression. A second cock N, Figs. 5 and 6, in the cylinder cover controls the admission of the air through the flap valve M, by partially closing which the admission of air is restricted, so as to reduce the pressure in the cylinder below that of the atmosphere at the end of the fall of the hammer; the blow is thus lightened by the excess of pressure of the atmosphere on the underside of the bottom piston I, which takes off at that moment a portion of its weight.

The two cocks L and N are both worked by one rod and handle O, Figs. 1 and 3; they are connected together so that when one is closed the other is open, and when the side cock L is shut, as in Fig. 5, so as to give the full force of the compression of the air upon the piston of the hammer, the upper cock N is then full open to give free entrance for the air and allow the unchecked fall of the hammer. The motion of these two cocks is so arranged, by making the lever of the upper one double the length of that of the other, that the first half of the upward motion of the handle O gradually throttles the opening of the upper cock N, keeping the lower cock L shut; while the latter half of the motion of the handle opens the lower cock L to its full extent, and continues to throttle still further the upper cock N.

A second handle P, Figs. 2 and 3, carries a projecting stud, which is used to hold up the hammer when required. A strap rod R works the driving strap on the fast or loose pulley F to start or stop the hammer; and serves also to regulate the speed at which the cam shaft is driven, by the slipping of the strap when only partially on the fast pulley.

In this hammer a light weight is raised, but a heavy blow is obtained from the increased velocity given by the recoil of the elastic air spring; and the great rapidity of the blows gives an important advantage in light forgings. The whole machine is readily under control, and a boy can work and instantaneously regulate it by moving the two hand levers, one shifting the driving strap for starting or stopping the hammer, and the other adjusting the inlet and outlet air cocks by which the force of blow is regulated. The value of this hammer where there are several strikers employed is strongly shown in working; and it can be made applicable for almost every kind of smith's work, doing as much as three or four strikers could do in the same time, and consequently saving heats, the importance of which in small forgings is a great consideration.

The hammer here described is one of the ordinary size, the falling parts being $4\frac{1}{2}$ cwt., with a cylinder of 10 inches diameter and 8 inches stroke; the total weight without the anvil block is 54 cwt., and the weight of block recommended is 30 cwt. The cost of working the hammer where there is shafting already running is small, scarcely indeed appreciable; and the cost of repairs is found to be very slight.

The CHAIRMAN asked how long any of the hammers had been at work.

Mr. T. WATERHOUSE said that one had been in operation 3 years at Mr. Goodfellow's works, and several others nearly as long; these were the first constructed and were not quite satisfactory in some points of detail, which had since been improved. There were only two yet working as now described, which were at the makers', Messrs. Beyer, Peacock and Co., and had proved thoroughly successful.

The CHAIRMAN observed that the speed of working the hammer would certainly be much increased by the application of the air cylinder. As to the mode of driving the hammer, he should hardly have expected the cam to clear sufficiently in working so as to avoid risk of being struck in the fall of the hammer. He enquired whether the partial slipping of the driving strap was found sufficient to regulate the speed of the cam shaft.

Mr. T. WATERHOUSE replied that all the regulation that was required in the speed was readily managed by that means; the strap was seldom entirely on, and was constantly shifted in position to regulate the speed of working as required; there was not found to be any objectionable wear of the strap from the slipping. The earlier hammers had been made with double cams, to give two blows at each revolution; but the present hammers could work at 130 blows per minute, without any objection to their being driven at that speed, the cam working quite clear of the roller in falling.

Mr. C. W. SIEMENS asked how long the cam could work without repair; it appeared that it must strike the roller with a blow whenever there was any piece of work on the anvil, as the hammer would then be prevented from falling to the bottom of its stroke, and the cam would consequently strike the roller some distance up, which would have the effect of a blow, and be liable to injure the cam.

Mr. T. WATERHOUSE replied that some of the cams had been at work for $2\frac{1}{2}$ years already, and the rollers for 2 years. The surfaces of the cam and roller were hardened, and they were found to be very free from wear; the cam lifted the hammer gradually at first, the curve of the cam and the position of the roller being so arranged as to allow of 2 or 3 inches variation in the fall without any inconvenience arising from the cam striking the roller.

The CHAIRMAN observed that the hammer seemed to be an intermediate tool between Nasmyth's steam hammer and Ryder's forging

machine. He enquired how the hammer was managed with the largest thickness, 5 inches, of work on the anvil.

Mr. T. Waterhouse said the height of the anvil block was adjusted if there were much alteration in the thickness of the work, the anvil face being changed to preserve the range of the hammer; there was not found to be any objection from that cause in the working of the hammer, and it was capable of doing all the ordinary kinds of light forging.

Mr. W. Froude remarked that the roller would probably continue revolving until the cam lifted it again, thus varying the points of contact between the cam and roller, and tending to ease the action and diminish the wear. He had seen a light hammer giving a great number of blows per minute employed in the block machinery at Portsmouth, in which the high speed was obtained by the recoil of a strong steel spring on the back of the hammer.

Mr. Henry Maudslay enquired what was the cost of the hammer.

Mr. T. Waterhouse said the cost of a hammer of the size described with the falling parts about 4 cwt. was £115, without the anvil block which was a casting of 30 cwt.

The Secretary stated that Mr. Beyer had been unexpectedly prevented from being present at the meeting. He had seen the hammer at Mr. Beyer's works, where it was in regular use, and it was stated to have proved very efficient and satisfactory.

Mr. R. Bach thought a great heat would be caused in the air cylinder by the compression of the air. In a vacuum hammer that he had at work, in which the hammer was lifted by opening a communication to an exhausted vessel, he had experienced a difficulty at first after working for some time from the stoppage of the air passage by the formation of a ring of ice in the valve box, in consequence of the great cold produced by the sudden expansion of the air in rushing into the exhausted receiver from the hammer cylinder; this had since been prevented by passing a steam pipe near the valve box to keep it warm.

Mr. T. Waterhouse said no inconvenience had been experienced from heating of the compressed air cylinder, even when the hammer had been at work six hours continuously; and it had to be noticed that in this case the air was partly changed at every stroke by a fresh portion being admitted from the external air.

Mr. C. W. Siemens remarked that there would not be any permanent increase of heat in the air cylinder, the heat liberated by compression being all absorbed again by expansion afterwards; but in the vacuum hammer that had been referred to the air was pumped out continuously, producing a permanent reduction of temperature by the continual expansion of air into the vacuum.

Mr. W. Froude observed that in the compressed air hammer, the mean pressure of the air being above the atmosphere, the average temperature would therefore be permanently above that of the external air, but this would probably be scarcely perceptible in practice from the conduction of heat away by the mass of metal.

The Chairman proposed a vote of thanks to Mr. Beyer and Mr. Waterhouse, which was passed.

The Meeting then terminated.

After the meeting a model was exhibited of Mr. Picking's Self-acting Boiler Feeder, for feeding steam boilers by means of a condensing apparatus regulated in its action by the level of the water in the boiler.

WOOD BEARINGS.

End Thrust Bearings of Screw Propeller Shafts.

Plate 20.

Fig. 1. *Longitudinal Section.*

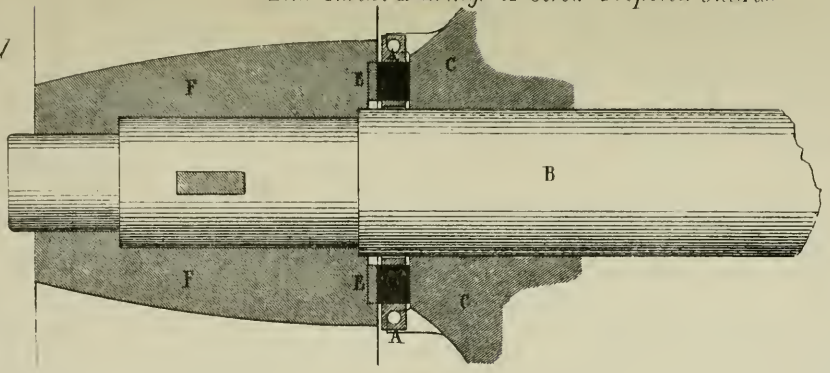


Fig. 2. *Transverse Section.*

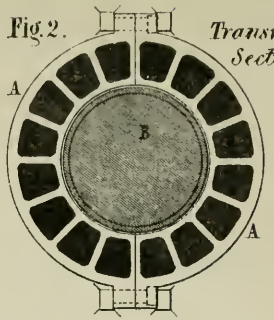


Fig. 3. *Longitudinal Section.*

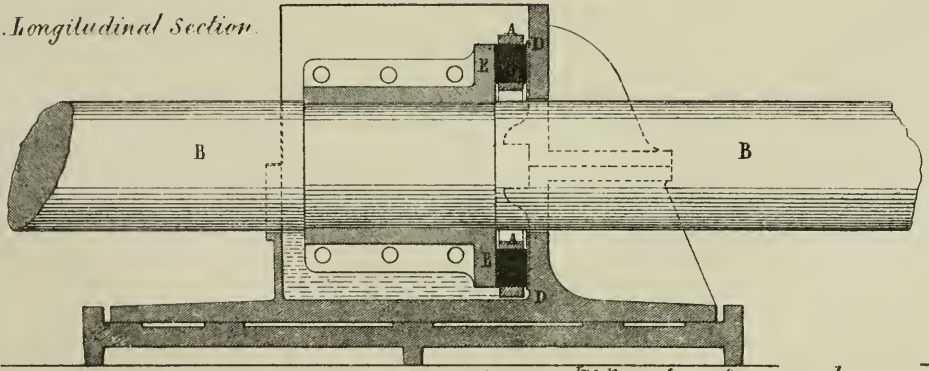
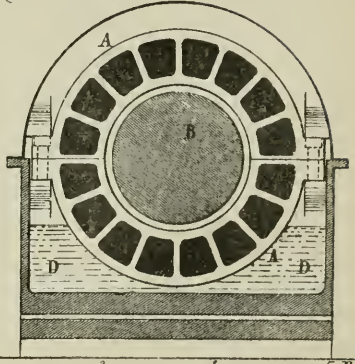
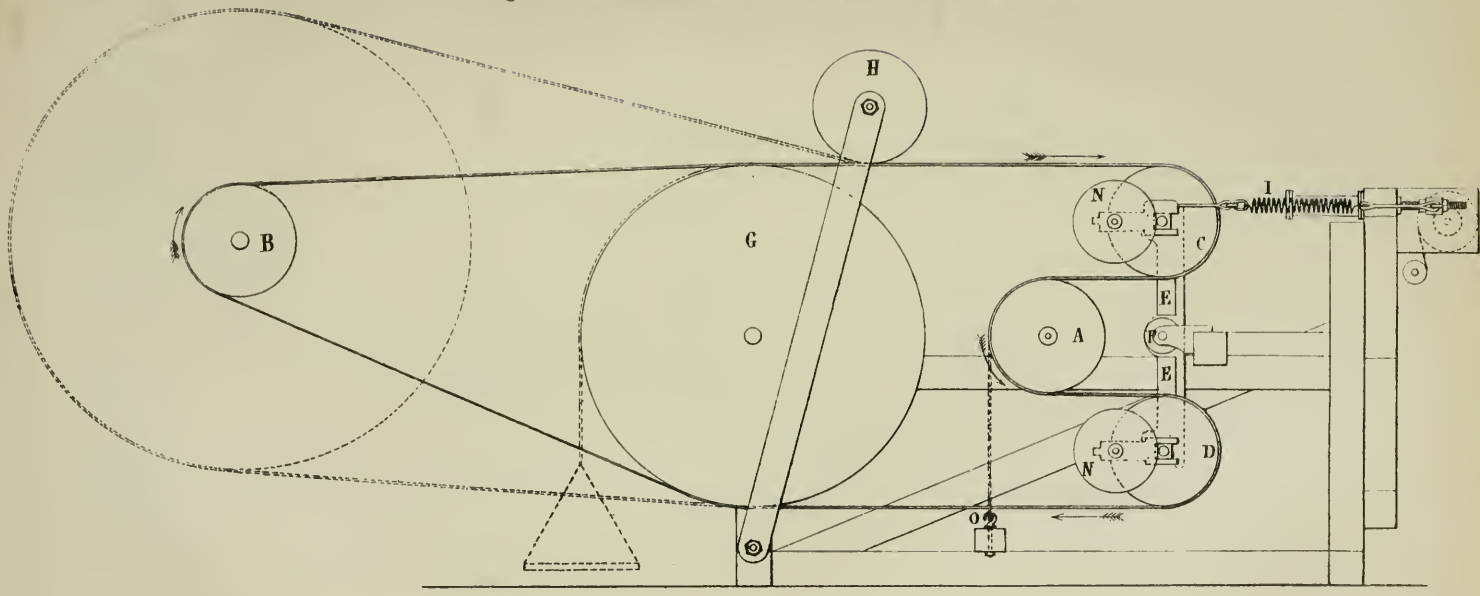


Fig. 4. *Transverse Section.*



(Proceedings Inst. M.E. 1858 Page 82) Scale 1/20th. Ins 12 6 0 1 2 3 4 5 Feet

Fig. 1. *Side Elevation of New Belt Dynamometer.*



(Proceedings Inst. M.E. 1858. Page 94)

Scale 1/20th. Ins. 12 6 0 1 2 3 4 5 Feet.

Fig. 2. *End Elevation of Belt Dynamometer.*

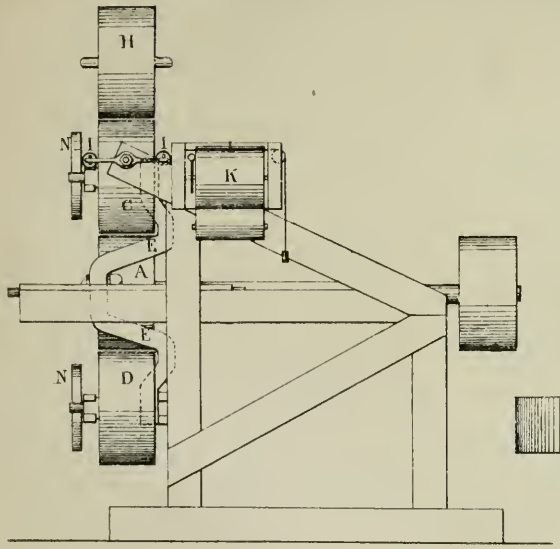
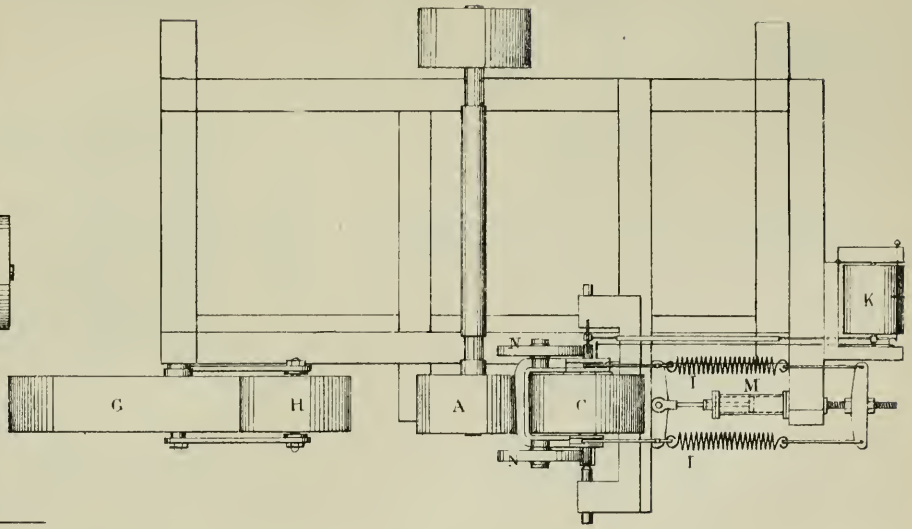


Fig 3. *Plan*



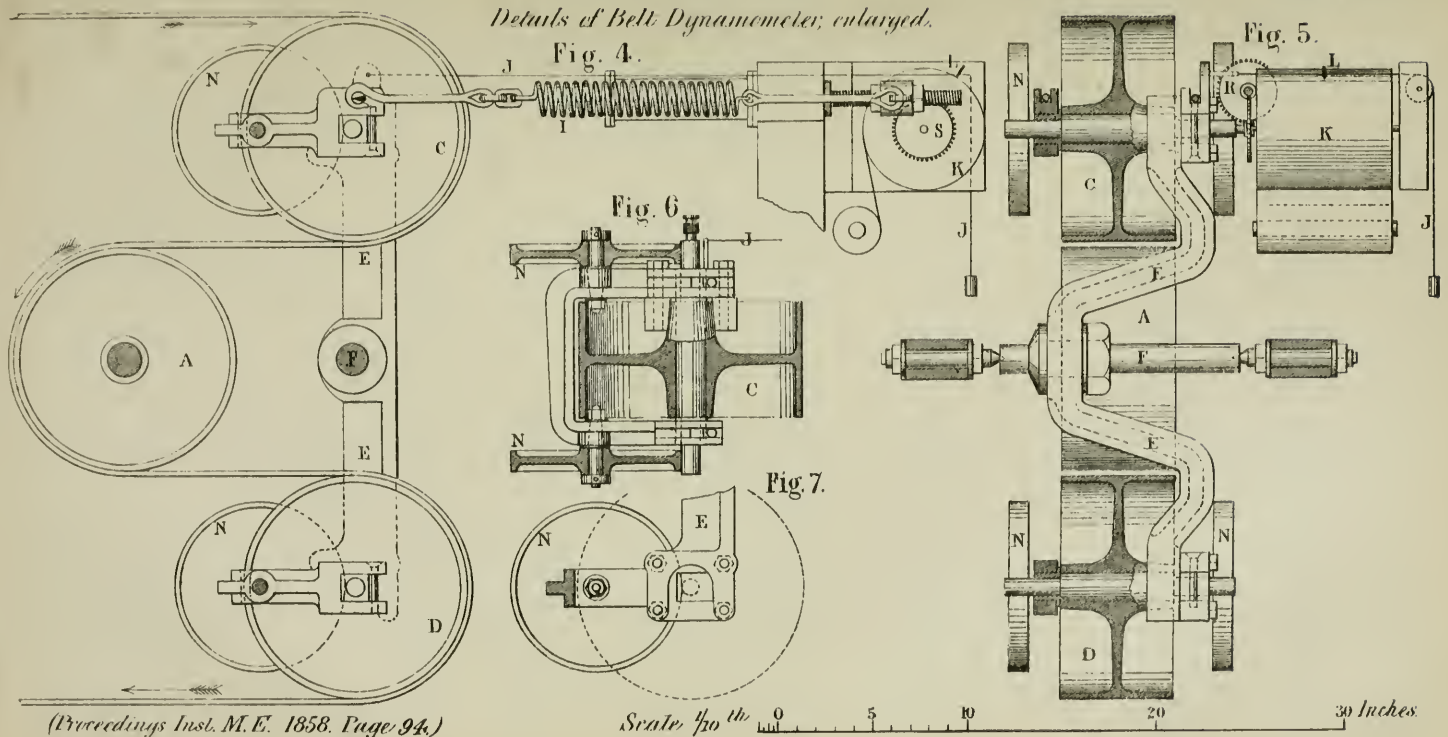
(Proceedings Inst. M.E. 1858 Page 94)

Scale 1/20th Ins. 12 6 0 1 2 3 4 5 Feet.

DYNAMOMETER.

Plate 23

Details of Belt Dynamometer, enlarged.



(Proceedings Inst. M.E. 1858. Page 94.)

Scale 1/10th

Diagrams taken by Belt Dynamometer at Cardiff 1858.

Fig. 8. *Thrashing Wheat. Total mean tension 110 lbs.*

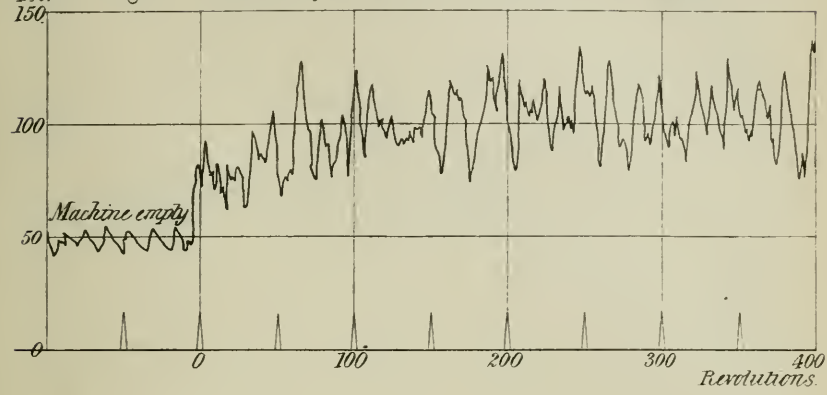


Fig. 9. *Thrashing Barley. Total mean tension 85 lbs.*

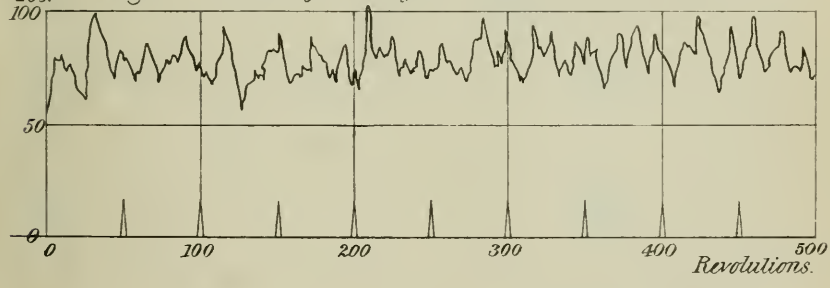
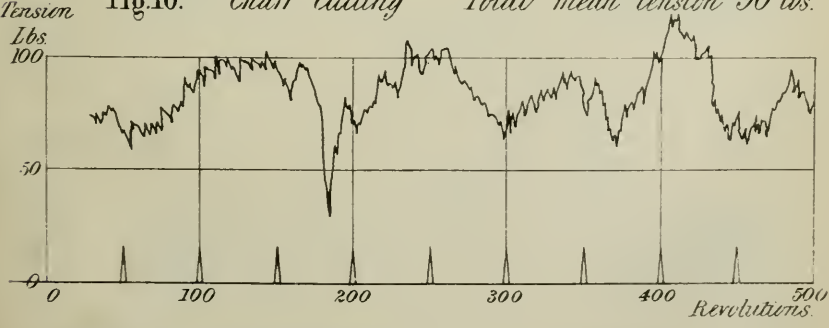


Fig. 10. *Chaff Cutting Total mean tension 90 lbs.*



(Proceedings Inst. ME 1858 Page 98.) *Scale full size.*

Fig. 11. *Side Elevation of New Friction Break.*

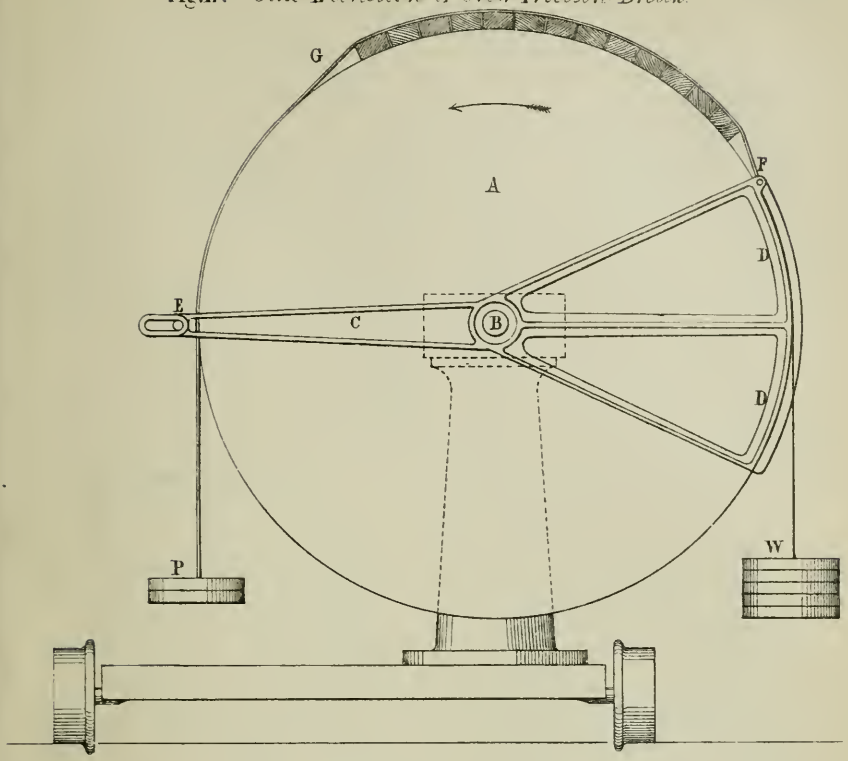
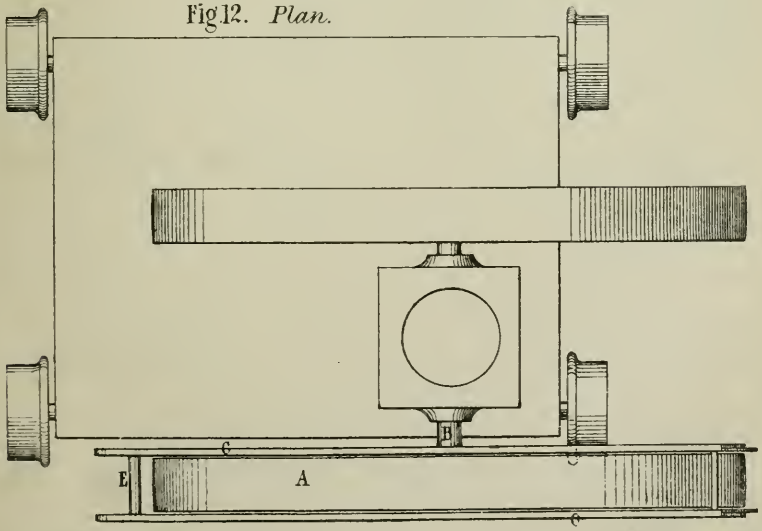


Fig 12. *Plan.*



Scale 1/20. Ins. 6 9 1 2 3 4 Feet.

(Proceedings Inst. M.E. 1858. Page 107.)

Fig. 13.

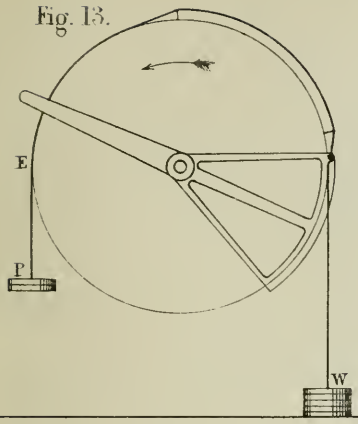
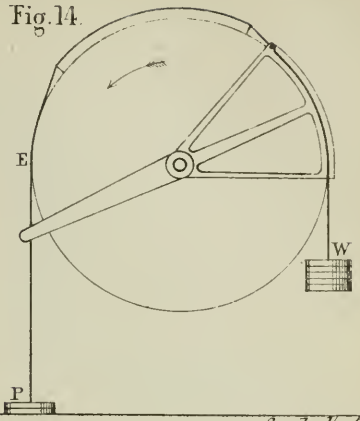


Fig. 14.



Scale 1/10th

Fig. 15.

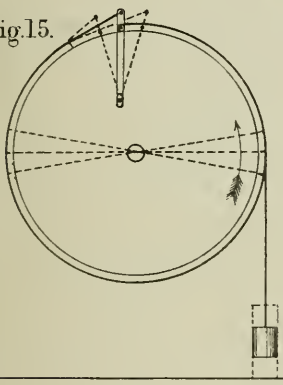


Fig. 16.

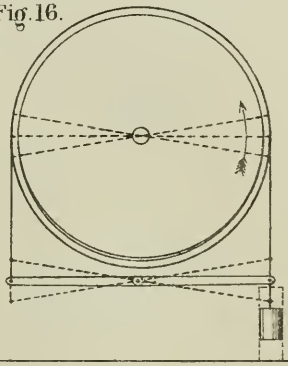


Fig. 17.

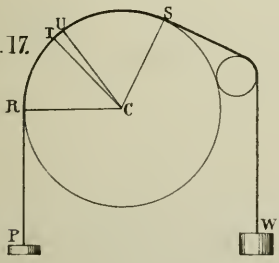
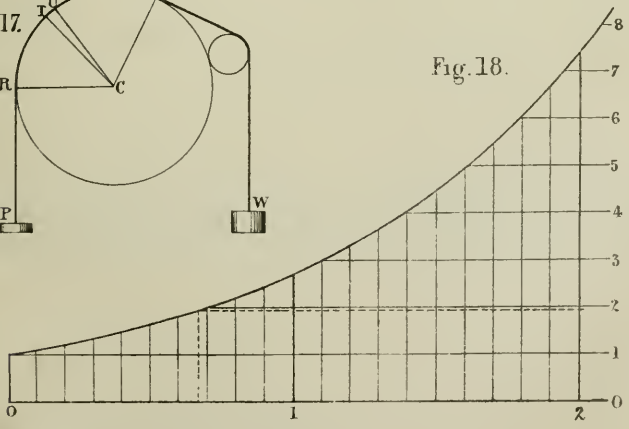
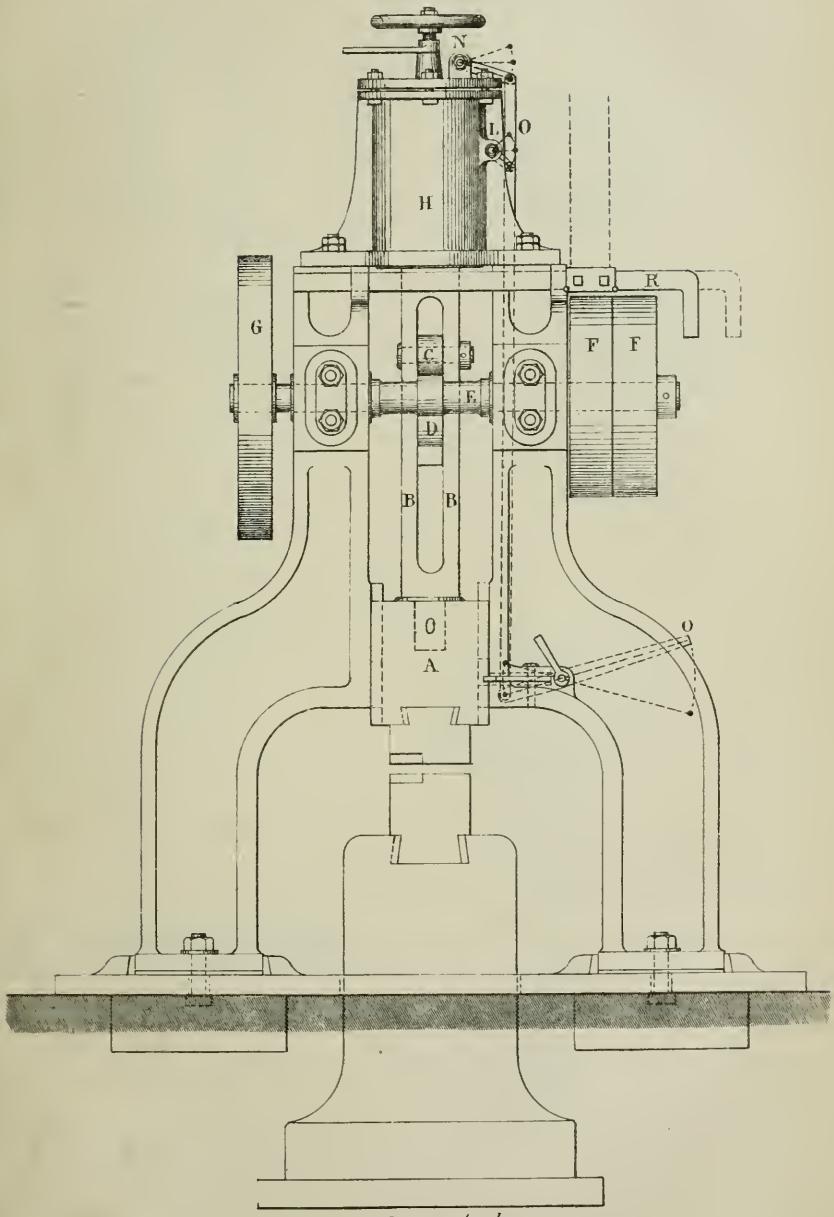


Fig. 18.



(Proceedings Inst. M. E. 1858. Page 104)

Fig. 1. *Elevation.*



Scale 1/20th.

Ins. 12 6 0 1 2 3 4 5 Feet

(Proceedings Inst. M. E. 1858. Page 118.)

Fig. 2. *Vertical Section.*

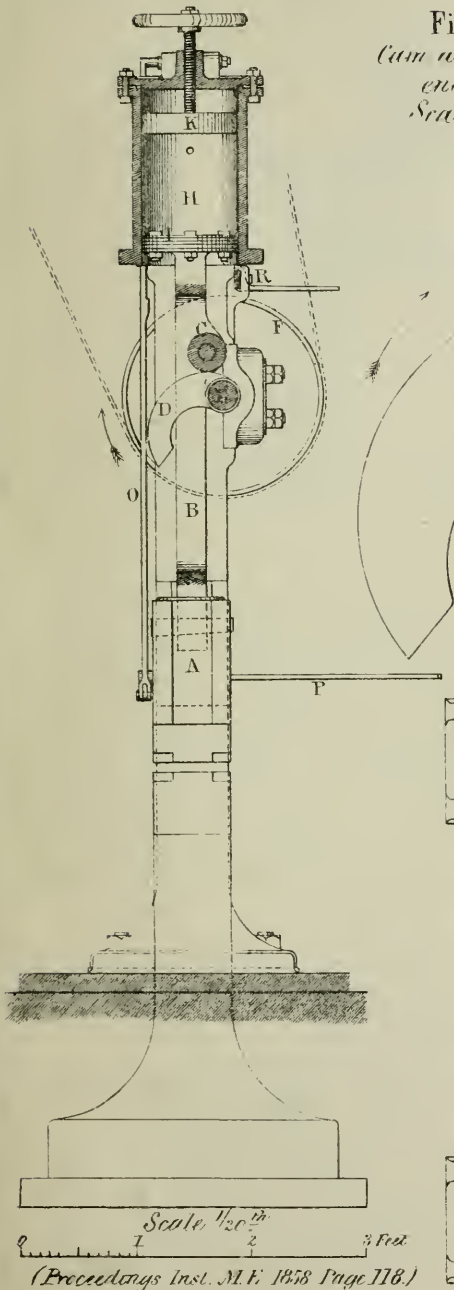
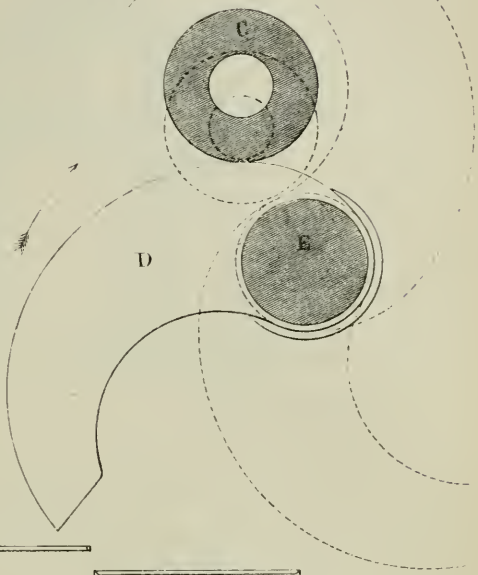


Fig. 4.
Cam and Roller enlarged
Scale 1/5th



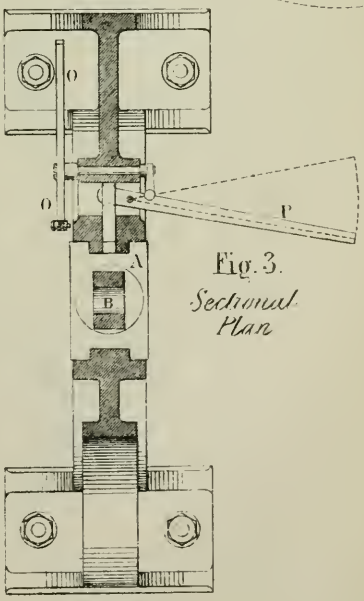


Fig. 3.
Sectional Plan

(*Proceedings Inst. M.E. 1858 Page 118.*)

Fig. 5. *Vertical Section of Air Cylinder.*

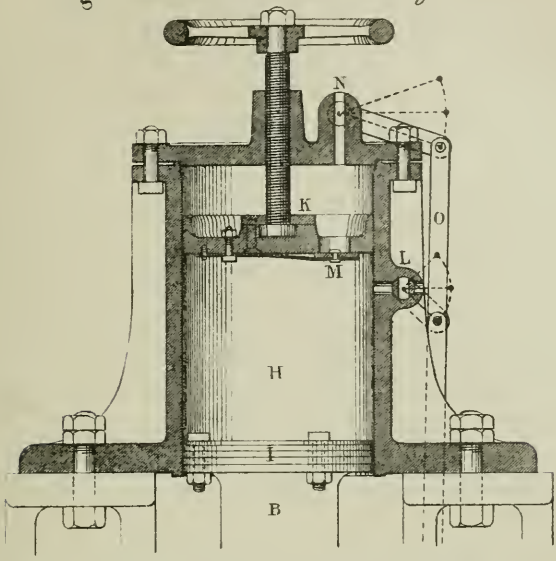


Fig. 6. *Plan at upper cock.*

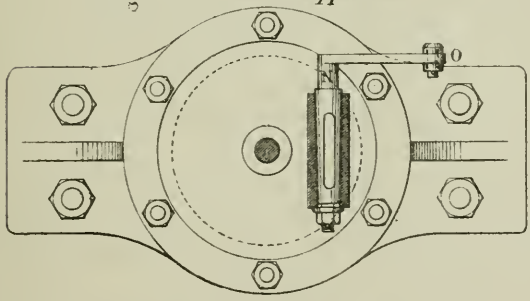
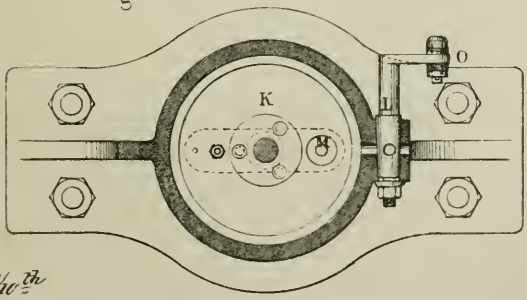


Fig. 7. *Plan at lower cock.*



Scale 1/10th

0 5 10 20 30 Inches

(Proceedings Inst. M E 1858 Page 118.)

PROCEEDINGS.

August 24 and 25, 1858.

The Special General Meeting of the Members was held in the Council Room of the Town Hall Buildings, St. Nicholas Square, Newcastle-on-Tyne, on Tuesday, 24th August, 1858; Joseph Whitworth, Esq., Vice-President, in the Chair.

The Secretary read the Minutes of the last General Meeting, which were confirmed.

The Chairman observed that the President, Mr. Penn, was unavoidably prevented by illness from taking the chair at the meeting, and much regretted that he was unable to be present on this interesting occasion. The Council had long looked forward with particular pleasure to this meeting in a locality to which the progress of Mechanical Engineering was so especially indebted, and he was sure it would prove of great interest and value to the Institution. They were greatly indebted to the excellent arrangements of the Local Committee, who had been most active and kind in their exertions and preparations for the meeting. It was very gratifying also to observe the large accession that had taken place to the numbers of the members in that district.

The following Paper, by Mr. William G. Armstrong, of Newcastle, was then read:—

ON WATER PRESSURE MACHINERY.

The subject of Water Pressure Machinery first attracted the writer's attention about twenty-three years ago, on occasion of his noticing a small stream of water which flowed from a great elevation down a steep declivity and turned a single overshot wheel near the end of its course. Observing that the portion of the fall which was thus utilised by the wheel was not more than a twentieth part of the whole descent, he was forcibly struck with the inadequacy of the wheel as a means of realising the power of such a fall; and conceiving it practicable to render the entire head available by bringing down the water in a pipe, and causing it to act by pressure upon a suitable machine at the bottom, he applied himself to devising an engine to be worked by such a pressure. Other inventors, guided by the same idea, had been previously led to apply water pressure in various ways to driving machinery, although the employment of that power had never been extensively adopted; but with these applications the writer was at the time wholly unacquainted.

After meeting with many difficulties and discouragements, the machine was produced, which after many years of seclusion in a lumber room has now been brought out for inspection upon this occasion. It is, as will be perceived, a species of rotary engine, admitting of a continuous and uniform flow of water through it, and exempt from all contracted passages. This machine was tried first in Newcastle, with the pressure from the street pipes equivalent to a column of about 200 feet; then in Gateshead with a still greater pressure; and in both cases it yielded a very high effect in relation to the theoretical power of the moving column.

Up to this time the writer's object had been merely to provide a machine for turning to profitable account the power which great altitude gives to mountain streams; believing then, as now, that when roads and railways have rendered accessible the valleys where such

streams abound, the water which descends from the heights will ultimately prove an efficient source of motive power. But having then had practical experience of the power residing in street water pipes, he conceived the idea of applying such power to the cranes at that time so slowly and expensively worked by hand upon the quay of this town. Accordingly after duly considering the means of effecting this purpose, a working model of a hydraulic crane was constructed, and exhibited at a meeting of the Literary and Philosophical Society of Newcastle, where it was connected with the town water pipes, and went through the several operations of lifting, lowering, and slewing in a very satisfactory manner. The next step was to carry this scheme into actual practice; and in the year 1846 the first hydraulic crane was erected at the upper end of the Newcastle Quay, where it has ever since continued to do good service in discharging ships. The crane model exhibited to the present meeting is nearly identical with the original model, and does not differ materially from the first actual crane erected in this town.

The writer was soon enabled to introduce the hydraulic crane at Liverpool, and shortly afterwards at the New Dock at Grimsby, where, at the instance of his friend, the late Mr. Rendel, the engineer who constructed that dock, he also applied the same kind of machinery for opening and closing the lock gates and sluices. An extensive system of water pressure machinery was accordingly carried out at that dock; and the result afforded the first practical demonstration that the pressure of a column of water could be advantageously applied as a substitute for manual labour, not merely for the cranage of goods, but also for various mechanical operations in connexion with the entrances to docks. At all these places the effective column of water was about 200 feet head. At Newcastle and Liverpool the supply was derived from the pipes communicating with the town reservoirs; but at Grimsby a tower was built for supporting a tank, into which water was pumped by a steam engine. In the former cases the irregularity of pressure, consequent upon the variable draught from the pipes for the ordinary purposes of consumption, proved a serious disadvantage; but this objection was not experienced at Grimsby, where the tank upon the tower furnished a separate source of power, undisturbed by

any interferences. But the erection of a tower was a formidable undertaking, and so long as it remained a necessity, a great extension of the principle could not be anticipated. The writer therefore resorted to another form of artificial head, which possessed the advantage of being applicable at a moderate cost in all situations, and of lessening the size of the pipes and cylinders by affording a pressure of greatly increased intensity. The apparatus by which this is effected is named the "accumulator," from the circumstance of its accumulating the power exerted by the engine in charging it. The accumulator is in fact a reservoir giving pressure by load instead of by elevation; and its use, like that of every provision of this kind, is to equalise the duty of the engine in cases where the quantity of power to be supplied is subject to great and sudden fluctuations.

The construction of the accumulator is shown in the vertical section, Fig. 1, Plate 30. It consists of a large cast iron cylinder A fitted with a plunger B, from which a loaded weight case C is suspended to give pressure to the water injected by the engine. The load upon the plunger B is usually such as to produce a pressure in the cylinder equal to a column of 1500 feet head; and the cylinder is made sufficiently capacious to contain the largest quantity of water which can be drawn from it at once by the simultaneous action of all the hydraulic machines connected with it. Whenever the engine pumps more water into the accumulator than passes to the hydraulic machines, the plunger rises and makes room in the cylinder for the surplus; but when, on the other hand, the supply from the engine is less for the moment than the quantity used, the plunger with its load descends and makes up the deficiency out of store. The accumulator serves also as a regulator to the engine; for when the plunger rises to a certain height, it begins to close the throttle valve in the steam pipe so as gradually to reduce the speed of the engine, until the descent of the plunger again calls for an increased production of power.

With regard to the pumping engine used for charging the accumulator, the most approved form is that of two high pressure cylinders fixed horizontally, with double-acting pumps directly connected with the piston rods. At first a simple plunger pump at each

end of the cylinder was used; then, with a view to greater compactness, the pump behind the cylinder was discontinued, and the other made a double-acting one upon the combined bucket and plunger system. Finally a modification of this form of pump was adopted, by dispensing with the clack in the bucket and substituting an external delivery valve D, as shown in Fig. 2, Plate 30. In this arrangement the out-stroke of the pump causes the water contained in the annular space surrounding the plunger E to be forced into the accumulator, while a further supply of water enters behind the piston F through the suction valve G; in the in-stroke the water behind the piston is discharged through the delivery valve D, and half of it passes round into the annular space on the other side of the piston, while the remaining half is forced into the accumulator, the area of the plunger E being exactly half that of the piston F. Each stroke of the pump thus delivers the same quantity of water into the accumulator. This neat modification of the bucket and plunger principle, by which equally easy access is given both to the suction and the delivery valves, was the suggestion of Mr. Henry Thompson, the writer's late intelligent foreman.

The introduction of the accumulator in the year 1851 removed all obstacles to the extension of water pressure machinery, which has since been applied in nearly all the principal docks, and in many of the government establishments in this country. Nearly 1200 hydraulic cranes, hoists, and other machines of that description have been applied; and 125 steam engines, collectively of more than 3000 horse power, are now daily at work to supply the pressure for working them. The system has also been adopted in many of the principal railway stations, not only for cranage, but also for working turntables, traversing machines, wagon lifts, hauling machines, &c. It is also extensively used for raising and tipping wagons in the shipment of coal, for opening and closing swing bridges, and for many other purposes. New forms of application are continually being developed, and no doubt can be entertained of its capability of further extension.

The form of mechanism which prevails to the greatest extent in these various applications of water pressure consists of a hydraulic press

with a set of sheaves used in the inverted order of blocks and pulleys, the object being to obtain an extended motion in the chain from a comparatively short stroke of piston. The general arrangement of the machinery for working a hydraulic crane is shown in Figs. 4 and 5, Plate 31; Fig. 4 being an elevation and Fig. 5 a plan. The pressure cylinder A for lifting the load is fixed horizontally below the surface of the ground in a chamber at the foot of the crane, and is fitted with the ram B carrying the pulleys C at its outer extremity. The lifting chain is made fast at one end to the cylinder A, and passes alternately round the moveable pulleys C and the fixed pulleys D at the inner end of the cylinder A; and is then led round the guide pulley E up the crane post F and along the jib to the load. The motion of the lifting chain is controlled by means of the handle G, acting upon the inlet and outlet valves which are kept closed by the weights H and I: by opening the inlet valve H the water is let into the cylinder A from the pressure pipe J, and raises the load; and by opening the outlet valve I the water escapes from the cylinder into the exhaust pipe K, allowing the load to descend. The travel of the ram B in the outward stroke is prevented from exceeding the proper limit by the pulley block C coming in contact with a stop connected with the handle G, which closes the inlet valve H and prevents the load from being raised too high. The return stroke of the ram is effected by the load suspended from the chain; and in the absence of any load a small supplementary ram L is employed to force the main ram B back, the slack chain being made to run out by the weight M.

To meet variation of load it was formerly the practice to combine three of the pressure cylinders so as to act either separately or collectively upon the lifting chain; but the writer has more recently introduced a method by which a variation of power is obtained with a single bored cylinder fitted with a combined piston and ram. Fig. 7, Plate 32, is a longitudinal section of the cylinder and valves of a double power hydraulic crane; Fig. 8 is a section of the piston enlarged; and Fig. 9 shows the valves in detail. A is the cylinder fitted with the piston E and ram B; the water from the accumulator enters the valve chest F through the pressure pipe J and the inlet valve H. For the lower power the water is admitted

to both sides of the piston E by opening the valve L, as shown in the drawing, in which case the power exerted and the water expended are each proportionate to the area of the ram B. For the higher power the valve L is closed and the valve M opened, so that the front side of the piston E is thrown open to the exhaust K, and the result both as regards power and expenditure is then proportionate to the full area of the cylinder A. It is seldom necessary to have more than a double power; but where a lower or third power is required a smaller ram may be inserted within the other, but in this case it is necessary to make fast the larger ram while the smaller one is at work. For lowering the load the valves H and M are closed and the outlet valve I opened, allowing the water to escape from the cylinder A into the exhaust pipe K; at the same time the valve L is also opened to allow the water to follow up the piston in the inward stroke.

In hydraulic cranes the power is applied not only for lifting the load, but also for swinging the jib, which latter object is effected by means of a rack or chain acting on the base of the moveable part of the crane, and connected either with a cylinder and piston, or with two single-acting cylinders applied to produce the same effect by alternate action. Figs. 4 and 5, Plate 31, show the arrangement of the two cylinders N and O for turning the crane, fitted with rams, acting by a chain passing round the base of the crane post F. The motion is controlled by means of a slide valve worked by a handle situated beside the handle G, so that while the water is admitted to one cylinder the other is open to the exhaust. The travel of the rams is limited by means of a tappet rod connected with the handle of the slide valve, whereby the crane is prevented from being turned round too far.

The absence of any sensible elasticity in water renders the motions resulting from its pressure capable of the most perfect control by means of the valves which regulate the inlet and outlet passages; but this very property which gives so much certainty of action tends to cause shocks and strains to the machinery by suddenly resisting the momentum acquired by the moving parts. Taking for example the case of a hydraulic crane swinging round with a load suspended from the jib, the motion being produced by the water entering into one cylinder and

escaping from the other, it is obvious that if the water passages be suddenly closed, the ram of the latter, impelled forwards by the momentum of the loaded jib but met by an unyielding body of water deprived of outlet, would be brought to rest so abruptly as to cause in all probability a fracture of the machine. So also in lowering a heavy weight, if the escape passage be too suddenly closed, a similar risk of injury would arise from the sudden stoppage of the weight, if a remedy were not provided. But these liabilities are effectually removed, in the case of a single-acting cylinder, by employing a relief valve in connexion with the water passages, consisting of a small clack valve N, Fig. 9, opening upwards against the effective pressure, so as to permit the pent up water in the cylinder to be forced back into the pressure pipe whenever it becomes subject to a compressive force exceeding the pressure given by the accumulator. In the case of a double-acting cylinder fitted with a piston and slide valve, or where two single-acting cylinders with rams working alternately are controlled by a slide valve, as in the instance of the cylinders N and O, Fig. 5, for turning the crane, relief valves are employed in connexion with the slide valve, consisting of four small leather flap valves arranged as shown in Fig. 6, Plate 31. The passages PP communicate with the pressure pipe J, and he passages EE with the exhaust K. When the slide valve is moved in the direction of the arrow, the pressure is first cut off from the port R by the lap of the valve, the port S being still open to the exhaust K; at the same instant the flap valve T opens upwards and allows a small quantity of water to pass from the exhaust K into the port R to follow up the ram until brought to rest. When the slide valve arrives at the centre position, as shown in the drawing, the port S is closed to the exhaust; and the pressure in the port S being increased by the further motion of the ram before it is completely stopped, the second flap valve U is raised and a small quantity of water forced back into the passage P communicating with the pressure pipe J. When the slide valve is moved in the opposite direction, the two remaining relief valves are called into action in the same manner. By these means all jerks and concussions are avoided, and perfect control over the machine is combined with great softness of action.

The method which the writer has most generally adopted for opening and closing lock gates by means of hydraulic pressure consists in applying to each gate a pair of cylinders with rams and multiplying sheaves similar to those constituting the hoisting apparatus in hydraulic cranes. One of these cylinders opens the gate and the other closes it, the whole of the machinery being placed in chambers beneath the ground, as shown in Figs. 10 and 11, Plate 33. The water is admitted from the pressure pipe J to the cylinder A through the inlet valve H by means of the handle G; the same motion of the handle also opens the outlet valve of the other cylinder B. The opposite motion of the handle G opens the outlet valve I, allowing the water to escape from the cylinder A into the exhaust pipe K, and at the same time admits the pressure to the cylinder B. A stop M connected with the handle G prevents the ram from travelling too far in the out-stroke, by closing the inlet valve; and the return stroke of the ram is effected by means of the weight L. This arrangement is in use at the Sunderland Docks, the London Docks, the Victoria Docks, and the West India Docks, and is now being applied to the new 100 feet entrance to the Liverpool Docks.

Another method has also been adopted for this purpose in some instances, which has been found to answer extremely well; Fig. 12, Plate 34, is a general plan of a dock entrance showing the arrangement of the lock gate machinery. Instead of connecting hauling cylinders with each gate, a line of shafting A, driven by a small water pressure engine B, is laid beneath the surface of the ground parallel with the coping on each side of the entrance, and by means of clutches is thrown into or out of gear with each gate crab. A wire from the engine extends the whole length of the shafting, so that the motion of the engine can be governed from the point where the work is being done. This method is already in use at several of the ports in South Wales, and is in course of being applied at the Jarrow Docks and the new dock at Silloth.

The rapidity with which dock gates can be opened and closed by these appliances is limited only by considerations of safety to the gates, and the operation is in practice usually performed in about two minutes.

The water pressure engines most recently constructed for driving the shafting consist of a combination of three oscillating cylinders

working cranks inclined at 180° to one another, with slide valves simply arranged, as shown in Figs. 13 and 14, Plate 35; and a small engine of this description is exhibited to the meeting. The cylinders A are fitted with plungers B instead of pistons, and are therefore only single-acting. The slide valves V are worked by the oscillation of the cylinders, communicated through the levers L. When the back end of the cylinder is depressed, the slide valve is lowered and allows the water to enter from the pressure pipe P through the pipe C to the cylinder, where it acts upon the plunger in the out-stroke. In the return stroke, the back end of the cylinder being raised, the cylinder port C is closed to the pressure pipe P and open to the exhaust E. A small relief valve is provided in connection with the cylinder pipe C, opening against the pressure, which prevents any shock when the communication with the exhaust is closed at the end of the return stroke. These engines have occasionally been made with pistons, so as to be double-acting; but for the heavy pressures employed where accumulators are used the single-acting arrangement with plungers is preferred.

In nearly all cases in which hydraulic pressure has been applied for the moving of dock gates, it is also used for opening and closing the levelling shuttles, and in many cases also for working the capstans. The former purpose is effected by the direct application of a cylinder and piston fixed above the shuttle; and the latter is accomplished by throwing the capstan C, Fig. 12, Plate 34, into gear with the shafting A, or by applying to it a separate engine similar to that which has been described. A good example of the application of hydraulic pressure to the opening and closing of scouring shuttles may be seen at Sunderland Docks, where by means of this power the enormous area of nearly 500 feet is opened in a few seconds and closed with equal rapidity.

At the same place an example may also be seen of a heavy draw-bridge worked by water pressure. The bridge is supported upon wheels, and is first lifted from its bearings to such a level as to enable the wheels to roll back upon a suitable railway, both operations being performed with great steadiness by the action of the water in little more than a minute.

In working swing bridges by means of water pressure, a central press is applied to lift the entire bridge clear of its supports, and it is then turned by an application similar to that used for slewing a crane. The most remarkable specimen of a bridge of this description is one erected by the writer at Wisbech under the direction of the late Mr. Rendel. In this case an opening of 85 feet is spanned by a double roadway bridge in one leaf weighing about 450 tons. At present it is but little used as a moveable bridge; but notwithstanding its great length and weight it can be lifted and turned in less that two minutes. The power is derived from an accumulator charged by hand labour, and it is expected that one man by continued working will be able to store up sufficient power for opening and closing the bridge as often as necessary. This system of using an accumulator in connection with a hand force pump has also been successfully applied to a drawbridge erected by the writer near Carmarthen on the main line of the South Wales Railway; and it might be advantageously adopted for many other purposes requiring a concentrated exertion of power with intervening periods of inaction.

Amongst the numerous applications that have been made of water pressure for the purpose of rapidly lifting and lowering heavy loads, there is one which calls for special remark on account of its growing importance: namely, its application in connection with an accumulator for working vertical hoists at the landing stations of steam ferries, in cases where a railway traffic is required to be passed over a river or estuary not easily crossed by a bridge. The traffic of the Aix-la-Chapelle, Dusseldorf, and Rhurort Railway is by this means shipped and unshipped at the ferry across the Rhine; and such is the rapidity and facility of the operation that a train of 12 coal wagons, weighing collectively 133 tons, can be transferred from the deck of the steamer to the railway, a height of about 20 feet, in 12 minutes. Each hoist lifts two wagons at a time, and raises its load in 10 or 12 seconds. These hoists are so arranged as always to accommodate themselves to the level of the boat, and always to stop at the exact level of the railway.

It is not necessary to say more upon that branch of the subject which embraces the two important principles of accumulation and

transmission of power, by means of which a steam engine can be economically applied to give safe and rapid motion to a multiplicity of machines intermittent in their action and distant from each other. But it remains to notice the applications made by the writer of the pressure derived from natural falls.

When the moving power consists of a natural column of water, the pressure rarely exceeds 250 or 300 feet; and in such cases he has employed to produce rotary motion, in preference to the original scheme of a rotary engine, a pair of cylinders and pistons, with slide valves resembling in some degree those of a high pressure engine, but having relief valves to prevent shock at the return of the stroke, as shown in Fig. 6, Plate 31, already described. Where the engine is single-acting, with plungers instead of pistons, as in the water pressure engine already described, the relief valves are greatly simplified, and in fact are reduced to a single clack in connexion with each cylinder, opening against the pressure, which is the same as the relief valve N, Fig. 9, in the valve chest of the hydraulic crane. The water pressure engines erected by the writer at Mr. Beaumont's lead mines at Allenheads in Northumberland present examples of such engines applied to natural falls. They were there introduced under the advice of Mr. Sopwith, and are now used for the various purposes of crushing ore, raising materials from the mines, pumping water, giving motion to machinery for washing and separating ore, and driving a saw mill and the machinery of a workshop. In all these cases nature, assisted by art, has provided the power. Small streams of water, which flowed down the steep slopes of the adjoining hills, have been collected into reservoirs at elevations of about 200 feet, and pipes have been laid from these to the engines.

Another application of hydraulic machinery at the same mines is now being made in situations where falls of sufficient altitude for working such engines cannot be obtained, which from its novelty deserves special notice. For the purpose of draining an extensive mining district and searching for new veins, a drift or level nearly six miles in length is now being executed. This drift runs beneath the valley of the Allen nearly in the line of that river, and upon its course three mining establishments are being formed. At each of these

power is required for the various purposes above mentioned, and it was desired to obtain this power without resorting to steam engines. The river Allen was the only resource, but its descent was not sufficiently rapid to permit of its being advantageously applied to water pressure engines. On the other hand it abounded with falls suitable for overshot wheels, but these could not be applied to the purposes required without provision for conveying the power to many separate places. Under these circumstances it was determined to employ the stream through the medium of overshot wheels in forcing water into accumulators, and thus generating a power capable of being transmitted by pipes to the numerous points where its agency was required. In this arrangement intensity of pressure takes the place of magnitude of volume, and the power derived from the stream assumes a form susceptible of unlimited distribution and division, and capable of being utilised by small and compact machines.

A somewhat similar plan is also adopted at Portland Harbour, in connexion with the coaling establishment there forming for the use of the navy. The object in that case is to provide power for working hydraulic cranes and hauling machines, and more particularly for giving motion to machinery arranged by Mr. Coode, the present engineer of the work, for putting coal into war steamers. A reservoir on the adjoining height affords an available head of upwards of 300 feet; but in order to diminish the size of the pipes, cylinders, and valves connected with the hydraulic machinery, and also with a view of obtaining greater rapidity of action, a hydraulic pumping engine and accumulator are interposed, for the purpose of intensifying the pressure and diminishing the volume of water acting as the medium of transmission.

In concluding this survey of the system of water pressure machinery which has grown to such large proportions, chiefly during the last seven years, the writer feels that the present occasion has afforded the fittest opportunity he could have taken of communicating the particulars contained in this paper; and he trusts that the details of the progress of this system may not have proved uninteresting.

Mr. W. G. Armstrong exhibited a working model of a hydraulic crane, and a specimen of the most recently constructed water pressure engines of 8 horse power, together with the original model engine that was first contrived for the purpose. He observed that the application of water pressure to produce rotary motion in an engine was not successful until the relief valves were designed; the great difficulty experienced being the stubbornness of the water and its want of elasticity. The relief valves were almost equally important in hydraulic cranes and other machines of that class: if in lowering a weight by the crane, the outlet valve for the escape of the water were suddenly closed, the piston would be still driven onwards by the momentum of the weight in motion; and as the water was prevented from escaping in front of the piston by the valve being shut, something would inevitably give way or burst to relieve the sudden pressure, on account of the water jammed up in the end of the cylinder being incompressible. This was however entirely obviated by the adoption of the relief valves, and the effect of the momentum of the moving weight acting upon the piston was simply to force open the relief valve at the instant of the pressure in the cylinder becoming any greater than that in the pressure main, allowing a little of the water to be squeezed back into the main through the relief valve. In consequence a heavy weight could be lowered rapidly, and the outlet valve be then suddenly closed; but the weight still proceeded a little further, and was stopped softly, without any shock or jerk, the motion being gradually retarded by the resistance of the uniform pressure of the water column acting upon the front of the piston through the opening of the relief valve into the pressure main; this caused the non-elastic water to act as if elastic, and with the advantage that the pressure could never exceed that of the original water column. In slewing the crane round in either direction the same cushioning action was obtained; the crane could be swung round quickly and the valve suddenly closed shortly before reaching the required spot, when the whole moving weight was safely brought to rest without any shock, by the effect of the resisting pressure steadily opposing its motion. The action of the relief valves gave the water in fact a sort of fictitious elasticity, which was just what was wanted in stopping the motion of

heavy bodies; and there was no waste attending this action, as the water was simply forced back into the store of the pressure main. In the case of slewing the crane round, the moving weight dragged the piston forwards a little after the water was shut off, leaving a vacancy behind the piston which was filled by the entrance of a little water from the escape pipe through the second relief valve, so as to allow the weight to come to rest gradually and without any recoil.

Mr. T. Sopwith considered that very important advantages were gained by this application of water pressure to drive machinery, as it admitted of the power being collected in reservoirs where it could be obtained without cost, and then conveyed to any distance where it might be wanted. The first of these engines had been applied under his own advice for drainage of water, and for raising, crushing, and washing the ore, at lead mines in a hilly district at Allenheads, Northumberland, belonging to Mr. Beaumont, where steam power would have been impracticable from the great cost of conveying coals to the works. Four of these water pressure engines had now been working in that neighbourhood for six years with complete success. He could bear testimony to the admirable working and the efficiency of these engines; and the results were so satisfactory that he was having three others erected at the new works now in progress in the same district.

Mr. W. Fairbairn considered the country generally was greatly indebted to Mr. Armstrong for having worked out so completely this very useful and efficient engine, which would prove of great advantage in a number of cases where water power was supplied without cost by mountain streams, but had been hitherto lost from the want of suitable means for making the power available at places where it could be usefully applied for driving machinery. The system of relief valves that had been introduced was a very ingenious and beautiful plan for preventing the shock of the water at the stoppage of the piston, and removing the serious defect of non-elasticity in the water. He remembered having, about 20 years since, constructed an engine for forcing water under heavy pressure, and had experienced much difficulty from that cause; and was obliged to admit a little air under the piston in order to obtain a certain extent of elasticity, or the

engine would otherwise have knocked itself to pieces by the severe shock produced at each stroke.

These water pressure engines were certainly of great value for situations where coals could not be obtained for steam power, inasmuch as they were calculated to work economically; he would however like to ask their comparative value in cases where steam was available, and under what range of circumstances water could be applied direct as the driving power. He remembered in one of the early applications of Newcomen's steam engine, at Hebburn Colliery in that neighbourhood, the engine was employed to pump water on to a water wheel for driving the winding drum, before any attempt was made to apply the steam power direct to winding. The plan of a hydraulic hoist for a ferry was a valuable application for crossing railway trains over a river that could not be spanned by a bridge, from its great safety and certainty of action; and for working cranes the water pressure machinery was highly advantageous on account of the complete control that it afforded, and its soft action which greatly facilitated the lifting of heavy loads.

Mr. J. Anderson had several of the water pressure cranes in constant employment at Woolwich Arsenal, and great success and advantage had attended their working. He noticed one point that had not been referred to in the paper, the objection likely to be felt at first of liability to stoppage or accident of the machinery from the water freezing in winter time; but he could state that during two winters' work no difficulty had been experienced from this cause at Woolwich, and he had found that a single jet of gas kept burning under each crane in the frosty weather was sufficient to prevent any risk of its occurrence. Another point to be noticed was the construction of the joints of the pipes, as the success of such an apparatus mainly depended upon the perfection of the joints for standing under the heavy pressure to which they were exposed; but the very simple and perfect make of joint had proved completely successful, and they had no trouble from leaky joints.

There was also an important point of advantage in the great economy of working that was obtained by the use of water power cranes instead of hand labour; and a great saving was effected in

the cost of the work, as well as an important advantage in the expedition with which it was done. There had been £30,000 expended at Woolwich Arsenal for fitting up 10 hydraulic cranes with their pumping engines and boilers, during the Crimean war, for the purpose of loading vessels direct from the quay side by powerful self-acting cranes; instead of the previous plan of loading most of the vessels by means of barges, which involved two transfers of all the load and incurred very heavy expense and serious delay. The saving effected in the demurrage charge per day for the vessels whilst loading was found alone sufficient to clear off the whole of this outlay upon the machinery in a short time.

Mr. T. Sopwith observed in reference to the comparative economy of water power and steam, that it would depend entirely upon the local circumstances of the situation as to the cost of coals, and the extent of water supply. Wherever the carriage of coal became expensive, and water pressure could be obtained even at a considerable distance, there would be a great economy in employing water power, as the current expenses of working would be only the interest of the outlay in pipes for bringing the water to the place required. The water engines at Allenheads, already referred to, were situated at a height of 1300 feet above the sea, where a supply of coal could be obtained only with great difficulty and at a heavy cost; but there was an abundant and constant supply of water from the mountains, from a great height above. In such a case the relative economy of water power was of course very great, and it was in fact the only power practically attainable in some of the situations where hydraulic engines were employed in the Allendale mines.

Mr. T. E. Harrison had used the water pressure cranes extensively for several years, and could speak very highly as to their value and efficiency; at the Newcastle station this power had been constantly used for seven years in lifting all the coke for charging the locomotive tenders, the chaldron wagons being each raised by a hydraulic lift to an upper platform for discharging by shoots into the baskets on the coke stage so as to save all hand labour. The same power was also used for working the large engine turntable and the cranes in the goods warehouse. In the case of these cranes the pressure of water from

the town waterworks reservoir was the only pressure required, and the water used was afterwards supplied to the locomotive engines, having spent its pressure in working the cranes and been then discharged into the engine water tank; the power for working the cranes was thus obtained without additional cost, excepting a nominal annual payment to the Water Works Company for the use of the water in transit.

This water power was also more economical than any other for such cases as the extensive goods warehouses now constructing by the North Eastern Railway at Hull, with water pressure hoists and cranes; and they had in consequence come to the conclusion of doing away with all the cranes worked by steam power, and employing the water power throughout. Besides the greater economy in working, the water pressure machinery had also important advantages in convenience of application over a large extent of premises, and simplicity in construction and keeping in order. In the construction of this machinery there was not only great novelty in the details, but great mechanical skill was shown in perfecting the several portions so as to make the whole thoroughly satisfactory in working and durability; it certainly formed one of the greatest steps in the application of water as a moving power for machinery, and they could not too highly estimate the ingenuity displayed in working it out so completely, and the great value of this contribution to engineering science.

Mr. W. G. Armstrong observed that in the application of the water pressure machinery where an artificial head of water had to be obtained, as in the case of working dock cranes, the real source of the power was the steam engine employed in pumping water into the accumulator, and the water acted simply as a convenient means of storing up the power and applying it whenever wanted at the distant points where the work had to be done. In the early application of a steam engine to pump water for driving a water wheel, it would of course have been more economical to drive the machinery direct by the steam power, avoiding the loss of power attending the intervening water wheel; but that was not the present question, which in the majority of cases was simply as to the mode of transmitting power where the direct application of steam was not available, the power

having to be applied at numerous points, many of them a long way removed from the source of the power, and in different directions. At the Victoria Docks, in London, the area over which the power was extended was so great as to require four miles' length of mains to convey the water to the several cranes and hoists and the lock gates; and any system of shafting for the purpose was of course quite out of the question long before that extent of length was reached. Then it was not practicable to have steam engines in the warehouses, nor to extend steam pipes over the premises: so that there was no other plan than water pressure available for working the whole by power, excepting the use of compressed or exhausted air; but both these latter involved serious practical objections, such as the extent of power lost in the compression of an elastic medium by the liberation of heat and the increased defect of pumps, and the circumstance that the leakages could not be detected by sight as in the case of water or steam. With the water pressure system there was of course some loss of power from the friction of the water in the mains, &c., but in transmitting power to a distance some sacrifice was unavoidable; and this plan appeared to involve the least proportion of loss. But it was not so much a question of comparative economy of power as of safety and convenience; and in these respects no other means of transmitting power was to be compared with water pressure.

In the application to natural heads of water, it was an important consideration that these were generally met with in situations inaccessible for the erection and working of machinery, and where the power was not wanted; but by obtaining the power there free of cost, they could well afford to convey it to a distance where it could be employed for work, at the expense simply of the interest on the outlay for pipes and machinery. And as the means of communication by railways extended, no doubt this application of water power would become greatly extended, by enabling the work to be brought within reach of the source of power.

In reference to the construction of the joints in the hydraulic machinery, that point had been the subject of much attention, as the pressures employed kept increasing progressively; and the result was that he found no plan stood so well as a small ring of gutta percha

compressed into the joint, which was turned with a projection on one side fitting accurately into a corresponding recess on the other side of the joint, like a spigot and faucet, as shown in Fig. 3, Plate 30. The gutta percha ring was put into the bottom of the recess, which was in a dovetail form expanding outwards to confine the gutta percha in its place, and the ring was then compressed by screwing up the joint, which compelled the gutta percha to fill up the recess completely; and it was found that the water was unable to pass the joint at the greatest pressure that was employed in working. The gutta percha, so long as it was protected from the air and exposed only on the edge to the water, appeared to be imperishable; and this was found to be the best joint for the hydraulic machinery, and gave no trouble under any pressure that they worked to, amounting now to as much as 700 lbs. per square inch; the joints also admitted of being readily opened and re-made if desired.

As to the liability of accident from freezing of the water in the engines or mains, he had found that when they were buried in the ground the hardest winters had never affected them; and consequently no precaution was required in the ordinary cases, as the whole of the portion of the apparatus containing water was generally sunk below the surface of the ground. In the cases where any portion was raised above the ground, the simple precaution of a gas burner as had been described was quite sufficient to prevent any risk of freezing. A still more simple and equally effective method was to employ a cock for emptying the cylinder of water after each time of using in frosty weather; so that there was no water exposed to freezing, the pipes underground being sufficiently protected by their position.

Mr. W. Fairbairn observed that they had now in Manchester a pressure of about 200 feet head of water in the street mains, and the introduction of water power for driving certain descriptions of machinery was well worthy of consideration, to avoid the inconvenience and risk of accident attending the use of steam power in many situations, such for instance as hoists in warehouses, even where from the low cost of coals the water power might not be less expensive than steam power. From the improvements already effected in the application of water power he thought a further extension of the system might confidently be anticipated.

The CHAIRMAN observed they were greatly indebted to Mr. Armstrong for the very valuable and interesting paper he had given them, and the excellent models and specimens he had exhibited to the meeting; and he proposed a vote of thanks to Mr. Armstrong for his paper, which was passed.

The following Paper, by Mr. Thomas Spencer, of Newburn, was then read :—

ON THE MANUFACTURE OF THE UCHATIUS CAST STEEL.

The Manufacture of Cast Steel, of which this paper treats, although not directly in the department of mechanical engineering, is so much connected with it that a few words on that subject may be interesting to the members of the Institution. The quality of the materials used for all parts of machinery and for the tools employed in their construction is of the greatest importance. These materials should possess the greatest strength and tenacity, and at the same time a durable and uniform wearing surface. Now cast steel perhaps beyond all other available metals possesses these qualities, and it is only its great cost that has hitherto prevented its more general application. It has a bearing strength of nearly three times that of best forged iron, and having a perfectly uniform texture it wears equally; it must therefore be acknowledged that cast steel is the best material that can be used where lightness and strength are required, and for all parts of machinery that are subject to much wear and tear. Its great cost being the difficulty in the way of its extended application, the great object in view for some years past has been to find out some process of making cast steel of a good quality and at a price that would allow of its free employment. Amongst a great number of metallurgists who have within a very recent period directed their attention to this subject, may be mentioned Bessemer, Chenot, Uchatius, and others. It is intended in this paper to enter only into the details of the Uchatius process of making cast steel, as compared with the ordinary processes at present in extensive use, which are two:—the English or Converting process, and the German or Puddling process.

To compare these processes with the Uchatius process about to be described, it must first be considered what steel really is, and in what manner it may be produced. This point may be illustrated by the following series, comprising the various degrees of wrought iron, steel,

and cast iron, arranged according to the amount of carbon in each, beginning with the softest wrought iron, that is with the iron containing no carbon or the least amount of carbon :—

Soft Wrought Iron,	containing	0·0	per cent.	of Carbon.
Hard Wrought Iron	„	0·4	„	„
Soft Steel	„	0·5	„	„
Hard Steel	„	2·4	„	„
Cast Iron	„	2·5	„	„
Hard Cast Iron	„	5·0	„	„

In this series, beginning with the softest wrought iron containing little or no carbon, the proportion of carbon increases until there is $\frac{1}{2}$ per cent., which then forms soft steel ; a further increase of carbon up to $2\frac{1}{2}$ per cent. forms cast iron ; and the proportion of carbon increasing to 5 per cent. gives the hardest cast iron. Hence it appears that the operation of steel making may be effected in two methods :—either by adding a certain amount of carbon to pure wrought iron ; or conversely by taking away a certain amount of carbon from cast iron, removing at the same time the impurities of the cast iron.

The English or Converting process is carried on according to the first of these methods, by adding a certain amount of carbon to wrought iron. The cast iron is first made into wrought iron, which is then converted into steel, forming blister steel; this is broken into small pieces and melted in crucibles, which renders it homogeneous, and is then poured while fluid into ingot moulds, after which it is known as cast steel. The chemical changes which the cast iron has undergone in this process are : firstly, when it was manufactured into wrought iron all or nearly all the carbon was abstracted from it; and secondly, by the converting process a certain amount of carbon was restored to it; and finally, the steel thus produced was made homogeneous by melting and casting. It is evident that this is a very circuitous way of manufacturing cast steel, and it has the following disadvantages: the great loss of weight in manufacturing the cast iron into wrought; the difficulty in converting the wrought iron so as to carbonise it equally in all parts; the great length of time that this process requires for the production of cast steel, and the great cost of manufacture.

The German or Puddling process is effected by the converse method, by taking away a certain amount of carbon from cast iron. The pig iron is puddled in the same way as in making wrought iron, except that the process is stopped when a certain amount of carbon has been taken away, a point which it is difficult to judge of. This partially puddled iron, or so-called puddled steel, is then made homogeneous by melting it in crucibles in the ordinary way. The chemical change which the cast iron has undergone by this process is the abstraction of a portion of the carbon in the puddling furnace; and the puddled steel has then been rendered homogeneous by melting and casting. The disadvantages of this method are: the waste of iron by the puddling process; the uncertainty of getting equally decarbonised iron, owing to the difficulty of measuring the quantity of oxygen acting on the puddled metal; and also the cost of manufacture.

The Uchatius process is based upon the same principle as that last described, consisting in taking away as much carbon only as is required to produce steel, and removing at the same time the impurities of the cast iron. The first and most important of these objects is effected by bringing a certain measured quantity of oxygen, in the shape of oxides of iron, in contact with the cast iron, so that while the iron is hot the oxygen combines with the carbon and passes off in the form of carbonic acid gas. The purification of the cast iron from silica, sulphur, magnesia, &c., is effected by bringing the iron when it is in a melted state into contact with alkaline earths, so that the impurities combine with them and remain floating on the top of the melted metal.

In order to effect these two operations at the same time the pig iron is first melted in a furnace or ordinary foundry cupola, and then run into a cold water tank where it is reduced into small granules. The mode in which the granulation is performed is shown in Figs. 1 and 2, Plate 36: the cold water tank has a horizontal wheel placed in it at one end, provided with wooden floats dipping below the surface of the water, and driven at a considerable speed; the melted metal running into the tank from the furnace falls on the wheel, which scatters it in a finely divided state towards the deep end of the tank, and it falls to the bottom in the form of small granules. This granulated cast iron

is mixed with pulverised oxide of iron and some alkaline earths, and the whole put into the ordinary steel melting crucibles and placed in the furnaces and brought into a fluid state. The degree of hardness of the steel is thus capable of being regulated by the size of the granules and by the quantity of oxides used.

The chemical change which takes place in the crucible is as follows. Each granule being surrounded by the pulverised oxides &c., the decarbonisation takes place first on the outside of each granule, and so progresses towards the centre as the heat increases, the oxygen in the ores combining with the carbon in the granules and passing off as carbonic acid gas; if therefore during the process the granules could be examined, it would be found that the outside of each is entirely deprived of its carbon, the next portion partially decarbonised, and the centre not decarbonised at all; so that each granule would be composed of pure wrought iron, steel, and cast iron. By increasing the heat the cast iron centre portion of the granule first becomes fluid, and the granule bursts and falls by its own weight to the bottom of the crucible. At the same time the earths mixed with the ores melt and rise to the top, forming a layer of scoria or dross floating on the surface of the melted iron. Each granule of melted metal has therefore in falling to pass through the rising scoria; and it is in the passing through that the combination of the impurities of the metal with the alkaline earths takes place, so that the decarbonised iron on reaching the bottom of the crucible is cleansed from all impurities. The heat continuing to increase melts the outside portions of the granules, and the whole is reduced to one homogeneous fluid mass in the crucible, which is then ready for being poured into the ingot moulds. The iron contained in the oxides mixes at the same time with the fluid mass, and yields about 6 per cent. more of cast steel than the weight of granules put into the crucible.

The oxides employed in this process are iron ores of the finest quality, such as spathose and hematite, which are previously calcined and pulverised. The proportion of the oxide to the granulated iron is according to the hardness of steel required, say from 20 to 30 per cent.; the greater the quantity of the oxide employed, the greater the decarbonisation and consequently the softer will be the steel produced.

This process is attended with the following advantages: a rapid manufacture of cast steel, the pig iron being turned into cast steel in the space of a few hours; certainty in producing a uniform quality of steel, that is steel containing a determinate proportion of carbon, which is accurately determined beforehand by the weight of oxide mixed with the granulated iron; and less cost than the ordinary methods of making cast steel, since the processes are fewer and the materials used are simply pig iron and iron ores.

Some experiments in making cast steel by the Uchatius process have been made by the writer at the Newburn Steel Works, near Newcastle-on-Tyne, from which it appears there is little doubt that a very fine quality of cast steel can be produced at a cost little more than one half of that entailed by the common processes.

Mr. T. Spencer showed a specimen of steel bar made by the process described in the paper, which had been tested and broke with a load of 30 cwt. at the centre, the bar being 1 inch square and 3 feet length between the bearings; the deflection was $3\frac{3}{8}$ inches at the time of breaking. A specimen was also exhibited showing the welding of two pieces of the steel, and specimens of the granulated iron and the pulverised ore used in the manufacture, and of the bars and plates produced, with some volute springs made from the steel; also a piece of the steel twisted cold to show its toughness.

The Chairman enquired whether the tensile strength of the steel had been tested, and whether it was found as good for springs as the usual make of steel.

Mr. T. Spencer replied that he had not tested the tensile strength of the steel at present, but found it stood well in the volute springs that had been made of it, which had proved quite satisfactory in working.

Mr. W. Fairbairn asked whether any plates had been made of this steel such as the steel plates that were now being introduced for making boilers, which he considered a very important step towards increasing the safety of steam boilers.

Mr. T. Spencer replied that only some small plates had been rolled from the steel at present as a trial, but these had proved quite satisfactory; and he did not anticipate any difficulty in making any size required. It would be observed in the specimen exhibited, that the plate was quite sound on the edges, although it had not been rolled edgeways, but simply rolled down lengthways.

The Chairman enquired whether any trial had been made of manufacturing the steel into wire.

Mr. T. Spencer replied that no wire had been made from it at present; the bars and plates made had been hammered and rolled down direct from the ingots of cast steel.

The Chairman asked what was the comparative cost of the process as compared with the ordinary process of manufacturing steel.

Mr. T. Spencer replied that the total cost of the finished bars was about one half of that by the ordinary process; but where the makers hammered and rolled their own steel and the cost of the ingot only had to be compared, the proportion would be considerably less.

Mr. W. Fairbairn thought this process was a very important step in steel manufacture, and would prove of great advantage in the construction of machinery, if a sound uniform steel could be obtained at a moderate price. The bar of the new cast steel that was exhibited certainly showed great strength, having sustained nearly three times as great a weight as iron; and he thought in process of time they might reasonably expect to obtain plates cast and rolled of that manufacture at least double the strength of the present wrought iron boiler plates for the same thickness, and not much more expensive for the same strength; and it had now become a very important desideratum to get plates for boilers only half the thickness at present used, as the thinner plates were so much less liable to injury from overheating and unsoundness in manufacture.

Mr. T. S. Prideaux thought the dropping of the melted iron into water in the process of granulating it would have a beneficial effect in assisting to free the metal from sulphur, by the metal coming in contact with the water in a red hot state; the plan had been tried in Austria he believed with success. It was not at all easy to separate sulphur from iron by simple exposure to oxygen in atmospheric air;

and he thought the plunging of the highly heated granules in water would be the means of removing the sulphur to a considerable extent from the iron.

Mr. W. Smith thought the process that had been tried in Austria was that of Capt. Uchatius now described; the plan of granulation seemed a very ingenious and important step towards obtaining steel by the direct process of decarbonising, and offered the best chance of carrying that process to a successful and economical result. Great advances were being made at the present time in steel manufacture, and they were doubtless greatly indebted for these advances to the investigation of the subject that had been excited by the publication of Mr. Bessemer's plans, although he had not succeeded in all that he had attempted himself; and they were also much indebted to Mr. Binks for having called more minute attention to the chemical principles involved in the manufacture of steel. The new process described in the paper appeared to have effected a great success in obtaining cast steel by the direct process; and if the uniformity of quality could be maintained, the economy of manufacture would allow of the use of cast steel being extended to many important new applications, such as boiler plates, and steel wire for the manufacture of telegraph cables.

Mr. A. Lenz explained respecting the process, in the absence of his friend Capt. Uchatius, that the only object in dropping the melted iron into water was to effect its granulation, and not for the purpose of depriving it of sulphur. The process of this manufacture of steel was to decarbonise the cast iron by the action of oxides under a high temperature, the great object being to expose the largest possible surface of the iron to this action, and by granulation this object was obtained to a remarkable extent. As to the actual composition of the steel, Capt. Uchatius had come to the conclusion from the results of his observations that the best steel required some small portion of what are considered impurities, such as sulphur, silica, &c.; and that chemically pure steel was not the result to be aimed at; and he had found that even with $\frac{1}{4}$ per cent. of sulphur the steel was of good quality. The great desideratum was to make steel at a very cheap price; and he had hopes it

might even be practicable to apply it ultimately to the manufacture of railway bars.

Mr. J. Anderson observed that the first steps had certainly been accomplished towards obtaining a better material at a reduced cost, and this was a very important object to be aimed at. Mr. Binks had been the first to draw attention to the fact of steel containing nitrogen, which from his researches appeared to be an ingredient of great importance in the composition of the different qualities of steel, and he was not aware whether any further information had been obtained upon this point.

Mr. E. A. Cowper remarked that in the list of compounds of carbon and iron given in the paper the hard cast iron was put down as having the largest proportion of carbon; but he supposed it was not meant that the hardest cast iron was that containing the most carbon, as the extreme of soft grey iron was kishy from an excess of carbon. He asked whether the Uchatius process removed the phosphorus from the iron; and what were the results of Chenot's process, by which a spongy mass of iron was produced, which was then compressed and dipped into oil, converted, and worked into bars.

Mr. A. Lenz replied that only the good qualities of iron were attempted to be used for steel making by the Uchatius process, and the Indian and Swedish iron was principally used, containing very little trace of phosphorus, as it was doubtful whether any phosphorus could be removed in the process.

In Chenot's process the principle was to employ pure magnetic iron ore in powder, which was found in a few situations in the Pyrenees in a natural state of powder, and was separated by a machine from the earths mixed with it. This powder was put into a furnace like a cupola, within a tube in the centre protecting the ore from the fuel, and exposed to a great heat; the powder then became in a spongy state, by reduction to nearly pure iron, but was not able to melt. It was then compressed cold with great force under a hydraulic press to solidify the mass, and was finally carbonised by covering with mixtures of oils and other carbonaceous substances, and melted in a close crucible. He doubted the process being adapted for the actual manufacture of steel on any large scale, and thought it more suitable

for the laboratory than the shop; various articles had been made of the steel for trial, which he believed were of a good quality, although he thought there was not any regular manufacture carried on.

Mr. W. Fairbairn had seen the process in operation two years since in Paris, and the steel that was manufactured by that means was of good quality; but the process was carried out only on a small scale, and seemed scarcely suitable for any wholesale manufacture.

Mr. T. Spencer observed that a magnetic machine was employed to separate the iron from the earthy matter, when in the state of powder as found naturally.

The Chairman enquired what was the mode in which the process of granulation was carried out at his works in making the Uchatius steel.

Mr. T. Spencer replied that the pig iron was broken into 6 or 8 inch pieces, and was at first put into the cupola for melting in the ordinary way; but they had now constructed a furnace for the purpose, as the ordinary cupola rather increased the proportion of sulphur in the metal by absorbing some from the fuel: the new furnace was a kind of reverberatory furnace, melting the iron in a chamber separate from the fire. The fluid metal was then run into the granulating tank; and the granules of iron were collected at the bottom of the tank by drawing off the water.

Mr. R. Pilkington remarked that there was a kind of coke obtained from the seam of coal known as the Mountain Mine of Lancashire, which was quite free from sulphur and might be advantageous for the purpose.

The Chairman proposed a vote of thanks to Mr. Spencer for his paper, which was passed.

The following Paper, by Mr. William Fairbairn, of Manchester, was then read:—

DESCRIPTION OF A FLOATING STEAM CORN MILL AND BAKERY.

During the recent siege of Sebastopol it was determined, on the urgent recommendation of Assistant Commissary General Julyan, to effect an arrangement for supplying the troops daily with new bread and fresh flour from the grain of the surrounding country, by providing the means of converting the wheat into flour and baking it upon the spot by a Floating Mill and Bakery. The writer having been consulted as to the best means of carrying out this proposal prepared drawings and plans for the mills and ovens; and two iron screw steamers, subsequently named the Bruiser and the Abundance, were purchased by the Government for adaptation to this purpose, and were fitted with machinery by Messrs. William Fairbairn and Sons, the whole being completed in less than three months.

It is curious to trace the history of the means by which large bodies of men have been supplied with food, and the obligations assumed by states for provisioning their armies in times of war. We learn that, in the early period of Roman history, grain was the only article of food issued to the soldiers, and was ground by means of a hand mill, which formed a part of every man's equipment; the flour was simply worked into a paste called *puls*, which constituted the principal food. The constitution of modern armies and the peculiar character of modern warfare render the soldier however more dependent upon the cares of the administration than was the case with the ancients; and we have seen how prostrate and helpless they are, when deprived of the resources of a well-conducted and far-seeing commissariat. The French, Spanish, and other continental troops can live upon a moderate allowance of vegetable and farinaceous food, and a lump of oil cake will maintain a Russian for a week; but it is widely different with the English, who become disorganised when their rations fail. Under these circumstances it is a matter of essential importance to maintain a system of daily supply; and hence followed the introduction of the floating mill and bakery.

The mill machinery of the Bruiser is similar to that ordinarily employed on shore in this country, with such modifications only as were necessary to adapt it to its novel position, and fit it to sustain the constant and varying motion of the vessel at sea. These difficulties were overcome, and the mill was found to answer admirably, grinding in almost all weathers at the rate of 20 bushels or 1120 lbs. of flour per hour, and that at a time when the vessel was steaming at $7\frac{1}{2}$ knots or $8\frac{1}{2}$ miles per hour, both the mill machinery and the ship being propelled by the same engines, which were constructed by Messrs. Robert Stephenson and Co., of 80 horse power.

The arrangement of the floating mill is shown in Plates 37, 38, and 39. Fig. 1, Plate 37, is a longitudinal section of the vessel; Fig. 2, Plate 38, is a plan of the machinery with the decks removed and partly in section; and Figs. 3 and 4, Plate 39, are transverse sections of the vessel.

The mill machinery is all driven from the propeller shaft A, which is driven by the engines B; and the whole of the processes are performed without the aid of manual labour. The wheat is stored in the forehold of the vessel, and is raised by an elevator into the screw creeper C, which conveys it into the corn dressing machine D, where it is cleaned and winnowed. Thence it is again conveyed by the elevator E and the screw creeper F into the hoppers GG for feeding the mill stones HH, by which it is ground. The grain is fed to the stones by the silent feeders I, first introduced by the writer, and now in general use in this and foreign countries. After being ground by the mill stones H, the flour or meal is delivered into the screw creeper K, which conveys it to the elevator L, by which it is delivered into the flour dressing machine M; it is here freed from bran and filled into sacks, having been separated into a fine and coarse quality. This completes the whole process. The propeller shaft A is exposed under the mill stones, but covered by an iron trough N in the other parts of the vessel.

During the time the vessel was in harbour at Balaklava, the daily produce of flour from this mill was about 24,000 lbs., and that from very hard wheat, full of small gravel and consequently the more difficult to grind. It was originally intended that the mill should be capable of

producing 20,000 lbs. of bread per day, but it proved equal to a considerably larger production; and not the least important of its good qualities was that it never got out of order during the whole period of service in the Black Sea. From the reports made to the government at home respecting its working, it appears that important advantages were gained by the introduction of this machinery for the use of the troops. There is probably no description of food so essential to the maintenance of health and the recovery of the sick as fresh flour and fresh bread; and the salutary effects produced upon the health of the troops and the number of lives saved in the late war, by the abundant supply of wholesome bread and flour that was poured into the camp during the latter part of the siege, forcibly suggest the necessity of a light portable steam engine and mill for grinding being constantly attached to the camp, whenever or wherever an army takes the field. This can be done at a very moderate cost, and in the writer's opinion no army should attempt to take the field without it. The whole affair would not exceed the weight of a heavy siege gun, such as now accompanies our armies; and there appears no practical difficulty in the way of introducing an engine capable of supplying newly-baked bread, from an oven constructed in the smokebox of a portable locomotive engine mounted on wheels and prepared to grind at the same time.

The results of the working of the floating corn mill are given in the official reports at 20 tons of flour ground per day of 24 hours when constantly in full work; and 18,000 lbs. of bread in 3 lb. loaves produced daily from the bakery. This rate of work was continued uninterruptedly for many months, and the machinery answered completely the object intended. The total quantity of bread produced in 3 months from 1st January to 31st March, 1856, was 1,284,747 lbs.; and the expenses of working were £2017, or 3*s.* 2*d.* per 100 lbs. of bread made, including the expense of a sea establishment for the vessel which would not be required where the vessel was stationary. The quantity of flour ground in the same period was 1,331,792 lbs. with 358,172 lbs. of bran, the wheat supplied being 1,776,780 lbs.; the expenses of working were £2050, or 2*s.* 4*d.* per 100 lbs. of wheat ground, or 3*s.* 1*d.*

per 100 lbs. of flour produced. The total cost of the flour produced was therefore about 25*s.* 3*d.* per 100 lbs., the wheat costing about 18*s.* per 100 lbs., and the value of the bran being deducted at 7*s.* per 100 lbs. or less than 1*d.* per lb.

The grinding of wheat was found to be performed quite satisfactorily whilst the vessel was at sea, even in a heavy swell causing an excessive motion, which tried the fitness of the machinery for the work to an unusual degree; the grinding whilst the vessel is performing her voyage being obtained from the same power that propels her. On one occasion when the vessel was steaming 6½ knots or 7½ miles per hour, 10 sacks of 168 lbs. each or 1680 lbs. of wheat were ground per hour, and the mill was kept in constant work for 35 hours, the men being divided into watches of 4 hours each; the mill continued working well throughout, and was found to run more regularly than when the screw was disconnected.

Mr. E. A. Cowper enquired whether any difficulty was found in regulating the speed of the engines when grinding whilst the screw was disconnected, as the available power of the engines would be then very much greater than was required for driving the mill, probably many times what was required.

Mr. W. Fairbairn replied that the engines were working at only a quarter of their power when grinding alone, as there were only 4 pair of stones, requiring not more than 20 horse power out of the whole 80 horse power, the power of the engines; they could not therefore run so steadily when grinding alone, and they were found to work best when the screw was connected. The principal novelty in the plan was grinding afloat, and the practicability of this had been doubted so much when first proposed that great difficulty was experienced in getting the plan introduced; but it had proved in practice completely successful, and such a machine was clearly a very important addition to the equipment of an army when taking the field in a campaign. If it had been applied a year earlier in the siege there was no doubt it would have been of great service, and have been the means of saving many valuable lives.

Mr. W. Smith asked for some particulars of the floating bakery, and whether any special machinery was employed in that vessel. The application of machinery for the purpose described was undoubtedly an important step; great advantage had been already gained from the introduction of non-military engineers into the war department, as was shown by the improvements effected in the extensive works at the Woolwich establishment by mechanical engineers, and these advantages would be greatly extended in other branches when unfettered by the military system. The floating factory employed at the Crimea, which had been fitted up in the neighbourhood of Newcastle, was another instance of the value of the extension of mechanical appliances in connexion with an army; it had proved of great advantage, and afforded very important facilities in promptly effecting the repairs required, without the serious delay and loss that would otherwise have occurred.

Mr. W. Fairbairn replied that the general arrangement and construction of the ovens in the floating bakery was simply carried out upon the ordinary plan, and there was not any machinery of consequence employed besides the kneading machines; the ovens were made of cast iron lined with brick, and no difficulty was found in keeping them regularly at work and supplying the army with fresh baked bread every day.

Mr. J. Anderson considered the floating mill and bakery had been a source of great benefit to the army and made a very important addition to the provision arrangements. The floating factory that had been referred to was very effective, and had proved of great service in the war; the machinery had been constructed by a firm in Newcastle, Messrs. Smith, the engines were made by Messrs. Morrison of Newcastle, and he might add that the foreman and men were also from the same district, having been selected by himself from that neighbourhood; and certainly no portion of the army had served more efficiently than that factory and the men belonging to it.

The Chairman proposed a vote of thanks to Mr. Fairbairn for his paper, which was passed.

The following Paper, by Mr. Thomas Hunt, of Crewe, was then read:—

ON A NEW CONSTRUCTION OF RAILWAY SPRINGS.

A considerable portion of the material used in the construction of the ordinary laminated steel spring gives, in the writer's opinion, but little elastic action, and in fact acts more as the base upon which the other portions of the spring deflect; and hence he has been led to the conclusion that two important defects are inherent in that principle of construction, namely, a superfluous dead weight of material used, and an unequal strain upon the several portions of it. It then occurred to him that if the plates of a laminated steel spring could be arranged so as to act upon the principle of a series of beams directly connected with each other, and so that the number of plates in action might be determined to some extent by the load (which in all carrying vehicles such as tenders, carriages, and wagons, is well known to vary considerably), these defects would be removed, and a spring of the greatest practicable strength with the minimum quantity of material be the result. Many experiments were made to clear up these points, all of which proved conclusive as to the superior strength and elastic action of the plan of spring described in the present paper over the common construction.

Various modes of constructing this spring are shown in Plate 40. The cast iron shoes are made with a series of steps, and the ends of the plates bear independently on the several steps of the shoes; the whole spring being inverted as compared with the ordinary springs, the bottom plates being the longest. Each plate is arranged to carry its proportion of the load independently to some extent of any other plate, by the steps being made gradually deeper in succession, so that only the longest plates bear at first, and the other plates take a bearing successively as the deflection of the spring increases, giving a uniform elasticity under a variable load.

By tapering each of the plates in thickness or in breadth, from the centre to each end, a uniform deflection of the plates throughout their length is obtained. The result of this mode of construction is that a

spring about two thirds the length of an ordinary spring gives out as much elastic action: whilst if the same depth be retained its carrying power is much increased, and hence it follows that to do the same work a much lighter spring will suffice.

The facility for giving as much deflection as may be deemed necessary to each plate independently is an important improvement in this construction of spring, as it avoids any undue proportion of the work falling on such plates as from their length should not receive it. In consequence of the independent action of each plate, they are not required to be fitted to each other as in the ordinary make of springs; and hence their cost of manufacture is lessened by the expense of so much fitting.

In Plate 40 are shown the different forms of these springs that have been used.

Fig. 1 is a Wagon Spring with curved plates tapered in thickness.

Fig. 2 is a Wagon Spring with straight plates tapered in thickness.

Fig. 3 is an Engine Spring with straight plates tapered in thickness.

Fig. 4 is a Tender Spring with curved plates tapered in thickness.

Fig. 5 is a Tender Spring with straight plates tapered in breadth.

Fig. 6 is a plan of the spring shown in Fig. 5.

The following Table gives the particulars of experiments made on the comparative weight and deflection of the new springs, and of springs of the ordinary construction :—

TABLE.

Description of Spring.	Weight of Steel.	Length of Bearing.	No. of Plates.	Breadth of Plates.	Thickness of Plates.	Camber.	Load.	Deflection.		Permanent Set.
								Total.	Per Ton.	
	Lbs.	Ft. Ins.		Ins.	Inch.	In.	Tons.	Inch.	In.	Inch.
Common Spring	98	2 7½	12	3½	⅜	2½	2·70	1·62	·60	0·12
New Curved Spring	60	1 10	9	4	{ 1 × ⅜ / 8 × ¼ }	1⅝	2·70	1·12	·42	0·12
Common Spring	78	3 0	7	4	⅜	4½	2·05	0·75	·37	
New Straight Spring	66	2 9	6	4	⅜ to 3/16	⅝	2·05	0·69	·34	
New Curved Spring	56	2 4	6	4	⅜ to ⅛	1¾	2·05	0·62	·31	

The wagons in which the new springs are working are 14 ft. 6 in. long, by 6 ft. 2 in. wide, and 1 ft. 6 in. deep inside, and intended for 6 tons load; but they have been frequently loaded to 9½ tons, and the straight springs were then deflected downwards about ½ inch, but were still doing their work efficiently, no failure having occurred with them.

There are now about 350 of these springs in use on wagons and tenders upon different railways; several have been two years in regular work, and the results are very satisfactory, none of them having failed.

Mr. A. Allan said he had made trial of the new plan of springs for 2 years on the Scottish Central and other railways, and had applied them to a considerable number of the ordinary class of railway wagons, and found the result very satisfactory; the action of these springs was more easy under the variable circumstances of load, and there was an important saving in weight and cost as compared with the springs in ordinary use. The plan of spring was specially intended to meet the case of the variable load to which wagons were subjected, as the ordinary springs were simply made strong enough to carry the heaviest load without undue deflection, but with light loads they had such excessive rigidity as to be in fact little better than mere props with scarcely any elastic action. With the new spring however many of the plates were entirely off the bearing when the wagon was empty or only lightly loaded, and such portion of the plates only were in action at that time as were proportionate to the load; but when fully loaded all the plates were at work carrying the load. He had also made a trial of this plan of spring for an engine spring, but in that case the advantage in reference to a changeable load did not apply; there was still however the advantage of the complete action of each plate independently, and the reduction in weight and cost; the springs had been tried in an engine with a load of about 5 tons on each and were doing well, but they had not yet been long enough at work to give a definite result.

The Chairman observed the principle of the new spring was certainly best applied where there was a variable load, a case for which other springs did not provide, as they were uniformly strong whatever variation might take place in the load.

Mr. E. A. Cowper enquired how the tapering of the plates in thickness was effected, and whether it cost much, as that mode of graduating the strength of the plates would certainly make the most perfect construction if it were not too expensive.

Mr. A. Allan replied the tapering was done by the ordinary eccentric rolls used for spring making, only extended for the purpose of giving the length of taper required; and there was not any difficulty in getting the plates tapered, at a small cost of only 1*s.* or 2*s.* per cwt.; he considered this make was preferable to tapering the plates in width by shearing, as it kept all the bearings at the ends the full width of the plates.

Mr. J. Tomlinson asked whether a difficulty was not found from increased variation in the level of the buffers with the new springs, the present variable height of the wagon buffers in trains being a serious defect, which he was afraid would be increased owing to the more elastic action of the new spring.

Mr. A. Allan replied the springs were arranged for the same total deflection as the springs in ordinary use, so that there was no more variation in the height of buffers between empty and loaded vehicles; the difference in the deflection of the new springs was that with the lighter loads the deflection per ton was greater than with the ordinary springs, making the action easier for the lighter loads, the deflection per ton being reduced as the load increased. He had also tried the new springs by running the wheels over 2 inch wedges placed upon the rails, and they were found to have considerably more elastic action than the ordinary springs, as shown by the range of vertical oscillation indicated by a pencil fixed from the wagon frame and marking upon a card fixed upon the centre of the spring or axlebox.

Mr. E. A. Cowper observed that in the ordinary laminated springs the friction between the plates caused great resistance to their action; and keeping the plates separate throughout their length as in the new

spring would certainly make the spring more lively. In reference to the saving in weight of steel required for carrying the same load, he did not see how any material saving could be effected by that construction, unless it were by the tapering of the plates in thickness; and thought the main advantage would arise from each plate being at liberty to follow its natural elastic curve in bending, not being controlled by the adjoining plates as was the case in the ordinary springs, where the plates being supported by one another each one got a leverage over the end of the one below, causing a tendency of the plate to set up in the centre; this effect was often seen in springs by the plates gaping open between the centre and the ends. The fact of the springs being proportioned to their work, as explained by Mr. Allan, was an important point, so that a spring should have as much action or play when lightly loaded as when heavily loaded.

Mr. A. Allan said a more lively action was plainly shown in the new springs when working. The saving of weight was effected by getting a more complete action from the steel in each plate independently, for in the ordinary springs a portion of the steel was not fully called into action. There was also a saving of the cost of fitting the plates together, which was incurred in the manufacture of the ordinary springs; this fitting also had the disadvantage of interfering with the true action of the plates, as they were fitted together so as to bear on each other only at the ends, having spaces between them at the centre before being closed up; and the shorter plates then became unduly strained by being pressed down out of shape by the longer plates, whilst the latter were not doing their proportion of duty and consequently wasted steel.

Mr. T. Spencer had found that the greater elasticity of the spring enabled it to be shortened for performing the same duty, which effected a saving of material; and the shortening of the spring prevented its more lively action being carried to any objectionable extent.

Mr. A. Allan observed that the wear upon the ends of the plates was not so great as in the common springs, as each plate of the series took a separate bearing, instead of the top plate having to sustain the whole load; so that the pressure upon each plate end was much less, and the wear was distributed over them all, instead of being confined to the ends of the top plate alone.

Mr. T. S. Prideaux asked whether the new spring had been tried on any common road carriages; he thought the principle would be particularly applicable there, as whenever the load was light the present springs acted imperfectly from being proportioned strong enough to carry the full load; he had thought, in noticing the action of the springs in such vehicles as omnibuses where the load was subjected to great variation, that it would be a great advantage if the springs could be varied in strength with the load, and the plan of spring now described appeared to effect this to a great extent by a self-adjusting change.

Mr. A. Allan replied that only one trial had been made at present on a common road, where instead of the ordinary double plates for each bow of a spring in a dog cart, the inner plates had been made free, without coming to a bearing whilst there was only a light load of one or two persons; and taking a bearing only when there was a heavy load to be carried, the spring then having its full strength in action.

Mr. R. Laybourn enquired how the form of spring so different from that in ordinary use had been arrived at; whether it was designed in that form, or obtained in the course of experiments.

Mr. A. Allan replied that the spring had been invented by Mr. Hunt, who was unavoidably prevented being present at the meeting; the object that had been specially aimed at was to obtain a spring that would be equally suitable for working with light or heavy loads, and also to effect economy in the use of the steel.

The Chairman proposed a vote of thanks to Mr. Hunt for his paper, which was passed.

The following Paper, by Mr. William A. Fairbairn, of Manchester, was then read:—

ON AN IMPROVED CONSTRUCTION OF AXLEBOXES AND COUPLING RODS FOR LOCOMOTIVE ENGINES.

This construction of axlebox has for its object the introduction of an elastic cushion or spring of vulcanised india-rubber between the axleboxes and framing of locomotive engines, for the purpose of allowing the wheels to accommodate themselves to curved portions of the railway, and thus to diminish the wear on the flanges of the wheels and on the faces of the axleboxes. The india-rubber spring is placed in recesses formed in the jaws of the horn plates upon each side of the axlebox, and a metal plate with a smooth casehardened surface is interposed, upon which the axlebox slides vertically with the inequalities of the road. The force of the spring action of the india-rubber is made sufficient to keep the axles of the wheels at right angles to the straight portions of the railway, but to yield to the friction of the rails upon the wheels in curved portions, and by this means to allow the axles to assume such a position as will place the wheels at a tangent to the curve. The elasticity of the india-rubber serves also to keep the axleboxes at all times in close contact with the faces of the horn blocks, so as to secure a good fit and obviate the necessity for that constant lining which they ordinarily require in consequence of the wearing away of the working faces.

The construction of the axleboxes is shown in Figs. 1 to 5, Plate 41, which represent the india-rubber applied to the trailing or leading and to the driving wheels of a locomotive engine. Fig. 1 is a half section and Fig. 2 a plan of an axlebox of the leading or trailing wheels; and Fig. 3 a side view, showing the position of the india-rubber washers.

A is the axlebox itself, B the jaws of the horn plate between which the axlebox slides; these jaws are recessed to contain the india-rubber springs C, and the face plates D which cover them. These plates are casehardened, and hence form an exceedingly smooth surface for the axleboxes to slide on; they rest upon the india-rubber

springs C, and a space of $\frac{1}{8}$ inch is left between them and the jaws B of the horn blocks, allowing the axlebox to play $\frac{1}{8}$ inch either way in the direction of the length of the engine, whenever the strain upon the wheels is sufficient to compress the india-rubber to that extent. That the leading and trailing wheels may have still further flexibility of adjustment, a small play is permitted to the axlebox laterally in the direction of the axle by making the recess in the axlebox, in which the plate D slides, wider than the plate itself by $\frac{1}{2}$ inch. But to keep the axleboxes in position in straight portions of the road, the plates D are made wedge-shaped in plan, so that the elasticity of the india-rubber restores the axleboxes to their central position whenever the pressure on the flanges of the wheels is relieved. The inclination of the wedge is made such that $\frac{1}{4}$ inch movement of the axlebox laterally in either direction compresses the india-rubber $\frac{1}{8}$ inch.

The india-rubber is employed in the form of rings or washers $\frac{3}{16}$ inch thick; and it is found convenient, in order to maintain an accurate fit between the working surfaces of the axleboxes, that these washers when in position should be compressed $\frac{3}{16}$ inch, which is equivalent to a pressure of about 1 ton on each side of the axlebox, tending to maintain the contact of the working surfaces. With this pressure the axleboxes slide more freely on the casehardened surface of the plates D than in the usual construction; whilst the motion which permits the wheels to accommodate themselves to the curvature of the road does not in the least increase the oscillation of the engine, and prevents the excessive wear of the shoulders of the journals and of the flanges of the wheels, which are such fertile causes of unsteadiness in ordinary engines. A specimen is shown of the vulcanised india-rubber taken from the axlebox of the leading wheel of an engine, in which it had run 17,000 miles; it is still uninjured, and retains its elasticity as perfect as when first introduced.

In the case of the driving wheels of the engine, it is not advisable to allow so much play to the axleboxes; and hence, whilst the admirable fit between the working surfaces obtained by the above arrangement renders its employment advantageous, it is modified in this case as represented in Figs. 4 and 5, which show a half section and plan of an axlebox for the driving wheels of a locomotive. The india-rubber E

consists of a flat band $12\frac{1}{2}$ by $2\frac{1}{2}$ inches and $\frac{3}{8}$ inch thick. It is covered by a wrought iron plate F, casehardened as before, but not wedge-shaped, since in this case all lateral play is to be avoided. A longitudinal play of $\frac{1}{32}$ inch only is allowed on each side between the casehardened plate F and the horn blocks G, to permit the action of the india-rubber spring, which is compressed in this case so as to exert an initial pressure of about 15 tons on each side of the axlebox to resist the action of the force driving the engine. Notwithstanding this large pressure on the working faces of the box it is found in practice to fall readily with the weight of the wheel itself. In the case of the driving wheel the advantage derived by this construction does not consist in the adjustment given to the wheels, but in the perfect fit at all times maintained between the sliding surfaces, the elasticity of the india-rubber making up for the wear of the axlebox, and obviating the necessity for lining up after a short period of running. The india-rubber also forms an elastic cushion to receive the shocks of the machinery. A small strip of leather shown at H, Fig. 4, prevents the oil from gaining admission to the india-rubber.

The perfect freedom of motion, the small wear of the axlebox in consequence of the casehardening of the slides, the ease with which the engine passes curves, and the diminished wear of the wheel flanges are important advantages, which have been derived in practice from this construction of axlebox.

In Figs. 6 and 7 is shown a similar application of an india-rubber spring I to the outside coupling rods of an engine. In this construction of rods the use of cotters for tightening the brasses is dispensed with by employing a set screw K at the end of the rod, secured by a lock-nut from risk of working loose.

Mr. W. Fairbairn showed a specimen of the india-rubber lining from an axlebox that had run 17,000 miles in a locomotive engine; also a model of the axlebox fitted up with india-rubber, and a specimen of one of the connecting-rod ends.

Mr. W. Smith was surprised at the good condition of the india-rubber after having run such a distance, as it did not appear to have suffered at all, and he supposed it must have been well protected from the action of oil or grease; if the india-rubber could be made to stand this application it would no doubt give an ease and softness to the working, and a saving in wear from diminishing the shocks.

Mr. W. Fairbairn believed the application had proved quite successful, and lessened the wear considerably; it was only requisite to take great care to keep oil away from the india-rubber, and in one trial the india-rubber had lasted only a month from neglect of this precaution, but when properly protected from oil its durability was found to be very great. A cap was now fixed over the india-rubber as a more complete protection for this purpose. These axleboxes and connecting rods were working in several locomotives on the Chester and Birkenhead Railway, and they were found to be now as good and perfect as when first put in, though some had run as much as 17,000 miles; they were considered quite satisfactory, and the result of the axleboxes was an improvement in reducing the wear of the wheel flanges. The connecting rods were screwed up at the ends, instead of being cottered as in the usual manner; and this mode of construction he considered an improvement as regarded convenience and security from accident.

Mr. E. A. Cowper thought a small degree of elasticity in the bearing of the axleboxes of carrying wheels, not driving wheels, might be of some advantage by easing the sudden shock upon the axle guards and wheel flanges, which would then take a soft hold, as it were, instead of a rigid one. He did not see however that the india-rubber lining for the axleboxes could have any effect in making the wheels run better round a curve, as the tendency of an axle was constantly to hang back at the outer end from the line of the radius of the curve, by trying to continue running in a straight line, and thus instead of conforming to a radius it would depart further from it.

Mr. W. Fairbairn replied the definite result that had been ascertained was a diminished wear of the wheel flanges where the elastic axleboxes were used.

The Chairman proposed a vote of thanks to Mr. W. A. Fairbairn for his paper, which was passed.

The following Paper, by Mr. John A. Haswell, of Gateshead, was then read :—

DESCRIPTION OF AN IMPROVED RAILWAY SWITCH.

In the various kinds of Switches now used on railways the moving tongue slides upon the chairs, rubbing upon them throughout the extent of its motion; and the switches are made self-acting by a balance weight hanging from the lever and constantly pressing the tongue home to the side of the main rail. But in practice this plan is found defective; for although a weight is employed as heavy as can be conveniently worked, its action is uncertain, being frequently impeded by the friction of the sliding tongue, from the chairs having become dry, or the oil becoming adhesive or mixed with sand and ashes; the tongue rails are then liable to remain on the wrong side, or only partially reversed, thus presenting both tongues open and causing danger of accident from wheels running off the rails by the flanges entering between the tongues and main rails at both sides. To lessen this defect a raised strip has been used upon the rubbing part of the chairs, which reduces the surface for holding sand; but this plan involves the objection of the oil being sooner rubbed off by the motion of the tongue, from the increased pressure between the rubbing surfaces. The large consumption of oil that takes place with the ordinary switches forms a serious item of expense, most of the oil that is applied being unavoidably wasted.

The new construction of switches described in the following paper, which is the invention of Mr. Edwin Thompson and Mr. William Nicholson of York, is designed to remove this difficulty, by avoiding the sliding of the tongue rails upon the chairs, and so dispensing entirely with the use of lubrication.

The construction of these switches is shown in Figs. 1, 2, and 3, Plate 42, which are a plan, side elevation, and transverse section of one of the switches. The tongues A B are of the ordinary form, but a short iron strut or link CC is jointed to the thin end of each tongue rail and to the end chair, as shown to a larger scale in Fig. 4; so that,

when the tongue rail is opening, this strut causes the end of the tongue to rise off the chairs, and the other tongue at the same time descends upon the chairs, the short strut acting as a radius link. The elevation of the tongue rail when open is 2 inches above the level of the main rails, which is found to insure the tongue rail being properly put down upon the chairs and closed to the main rail, and being also entirely clear from any low portions of the engines &c.

In this construction of switches, on account of the sliding motion and friction of the tongue rails being entirely avoided, oil is not required, and no danger can arise from sand or ashes lodging on the chairs; also the removal of any larger fragments of coke or ballast is to a certain extent provided for by the altered form of the chairs, which this manner of opening the tongue rails admits of. As the tongue rails require no larger surface to rest upon than is actually in contact with the chairs when they are closed to the main rail, advantage is taken of this by increasing the thickness of the chairs at the particular part upon which the rails rest, forming a raised step which is completely covered when the tongue rail is closed; and on the open side the width of the tongue rail only is exposed to the reception of rubbish, the larger pieces thus falling off, and the smaller ones being crushed or removed by the descent of the tongue. The accomplishment of this object has been satisfactorily shown by the working of one of these switches, which has been put down in a situation where sand was constantly used for the engine wheels, and has continued to work well although sometimes nearly buried by the accumulation of sand.

In these switches the ends of the tongue rails are extended a foot beyond the sharp edge that fits against the top of the main rail, and the extended ends are curved inwards like a check-rail end at DD, and reduced in height $1\frac{1}{4}$ inch to allow the wheel flanges to pass over the top when the tongue rail is closed to the main rail; and in any case of the tongue not being properly closed, the pressure of the wheel flange will tend to crush any obstructing substance upon the chairs. This action is aided by the check-rail end of the tongue on the opposite side, which in such a case will not be opened to the full extent, but sufficiently so to guide the wheel flanges in the proper course, and by

drawing them from the other imperfectly closed side prevent the wheels from taking both lines.

The advantages aimed at in these switches are safety and economy in use, on account of their working as well without oil as the ordinary ones do when clean and perfectly oiled, saving by this means a cost of at least twenty shillings per annum for each switch; the safety from risk of the switches being reversed when a train is passing over, either by a bent axle or other unusual strain, in consequence of the closed point being kept down by the weight of the train itself; and the convenience of these switches for shunting, for which no balance weight is required, the tongues being perfectly safe when standing on either side, thus requiring less attention from the men engaged with the trains. The application of this plan does not require any alteration in the dimensions or form of the ordinary switches in general use; and it can be applied easily and at trifling cost to those already fixed and in use.

Some of these switches are now in constant use at the York and Newcastle stations, where they can be seen in operation.

Mr. J. A. Haswell exhibited a large working model of the new switch.

Mr. J. Bourne had had one of the switches in operation at the Newcastle station for a month, and some others had been tried for about six months at the York station; these had been working very satisfactorily, and were found to have a decided advantage over the other switches in use. The others required constant oiling and attention to keep them in working order, and the oil collecting the dust and grit caused frequent cleaning to be necessary to prevent risk of accident from the switch sticking partly open. In winter great difficulty was experienced with ordinary switches from the snow, which pratially melted in the day time and then froze again in the evening, causing the switch tongue to be choked up by ice and prevented from

shutting close, and the men had to be continually using salt to thaw the ice, and keep the switches working. But these new switches were completely free from those defects, and appeared very successful in meeting the requirements of self-acting switches; no oil was used, and this effected an important saving in annual expense; and from the switch tongues not having any sliding motion on the chairs, no inconvenience was experienced from sand and dust, and the risk of their sticking partly open was effectually prevented, as they must fall on one side or the other.

The Chairman asked whether any special provision was required in boxing up the switches to protect them from injury.

Mr. J. Bourne replied the switches were all boxed up in the station yards to protect the connecting rods from the risk of being caught by the wagon coupling hooks; no other protection had been required for the new switches, and they had kept in complete order.

Mr. W. Bouch enquired whether an engine passing over the switch backwards opened the tongue as readily as in the ordinary switches.

Mr. J. A. Haswell replied that no difficulty was found in this respect, and the small-sized chaldron coal-wagons readily opened the tongues.

Mr. E. A. Cowper thought the new switch accomplished in a very neat and effective manner an object that had been much aimed at, and had been the subject of many ingenious schemes. One plan that had been proposed was to have inclined surfaces upon the chairs for the switch tongue to slide down; but there was an objection to an inclined plane in the risk of bending the tongue from the friction when the weight came upon it; and it was undoubtedly a favourable point if the use of oil and the sliding motion could be entirely dispensed with, as in the plan now described. The new switch would have a tendency to crush any stones, by dropping down upon them in closing; and it would certainly be less likely that anything would remain on the chairs than in the case of the ordinary switches, where the action in removing stones was by pushing them along, and there was the risk of some getting jammed in between the tongue and the main rail, and preventing the tongue from fully closing.

Mr. J. Tomlinson remarked cases were frequent of engines getting off the rails from a switch remaining half open, so that both tongues caught the wheel flanges; and thought it would be a useful improvement if this switch prevented the risk of sticking half open, by the tongues being sure to fall on one side or the other.

The Chairman proposed a vote of thanks to Mr. Haswell for his paper, which was passed.

The Meeting was then adjourned to the following day.

After the meeting the Elswick Engine Works were visited by the Members and their friends, where the hydraulic machinery was shown by Mr. Armstrong in operation and in process of manufacture: the accumulator was worked at a pressure of 700 lbs. per square inch, and applied to a 12 ton crane, and to work a large slotting machine and other machinery. Specimens were also shown of a new construction of wrought iron gun, made rifled and breech-loading.

At Low Elswick the experimental boiler was then seen, with which the series of trials had been recently made by a Committee appointed by the Coal Owners' Association, for ascertaining the most eligible mode of burning Newcastle bituminous coal in steam vessels without producing smoke whilst obtaining a large duty from the boiler. The boiler, which was of the ordinary multitubular form with two furnaces, was furnished with regulating slides and holes for the admission of air round each firedoor; by keeping these open to the required extent the continued combustion of the smoke was effected, and on shutting them dense smoke was shown to be at once produced; the coals used were Hartley Best.

In the evening a large party of the Members and their friends were invited by the Local Committee to a Conversazione held in the rooms of the Literary and Philosophical and the Natural History Societies, Westgate Street, which were kindly lent for the occasion.

A valuable and interesting collection was exhibited of models and drawings of machinery and engineering works, including a number of original drawings and photographs of early and recent locomotive and stationary engines ; also a collection of philosophical instruments, photographs, and stereoscopes, &c., and a fine series of objects under microscopes.

Fig. 3. Joint at J Half size.

Fig. 1. Vertical Section of Accumulator.

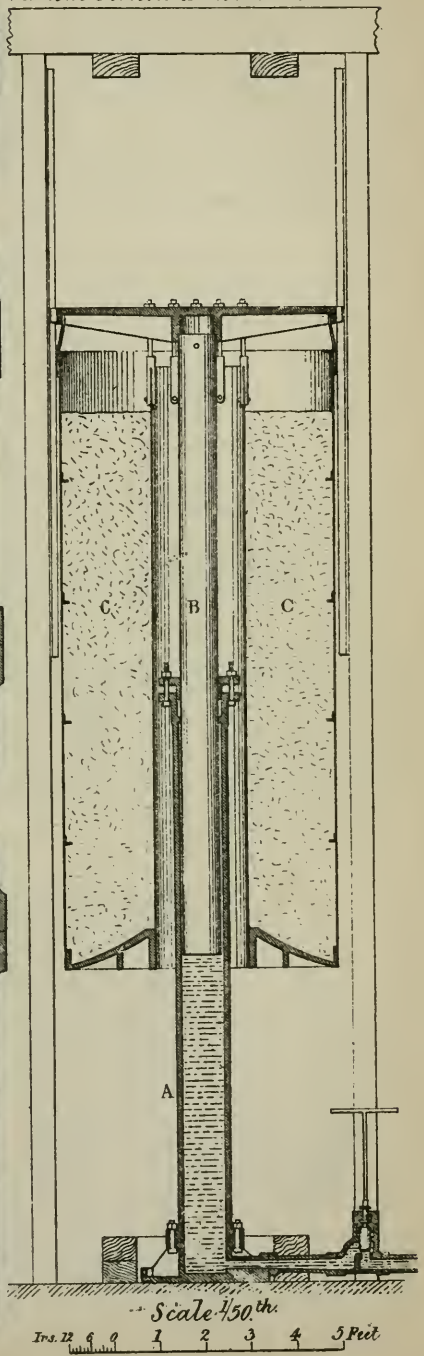
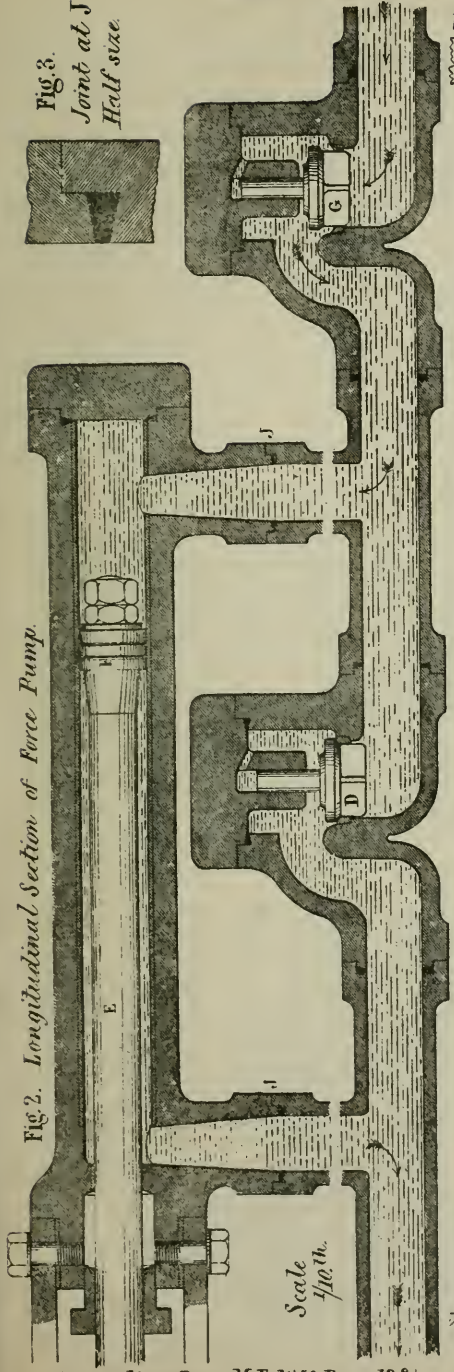


Fig. 2. Longitudinal Section of Force Pump.



(Proceedings Inst. M.E. 1858. Page 128.)

Hydraulic Crane.
General Arrangement of Machinery.

Fig. 4. *Elevation.*

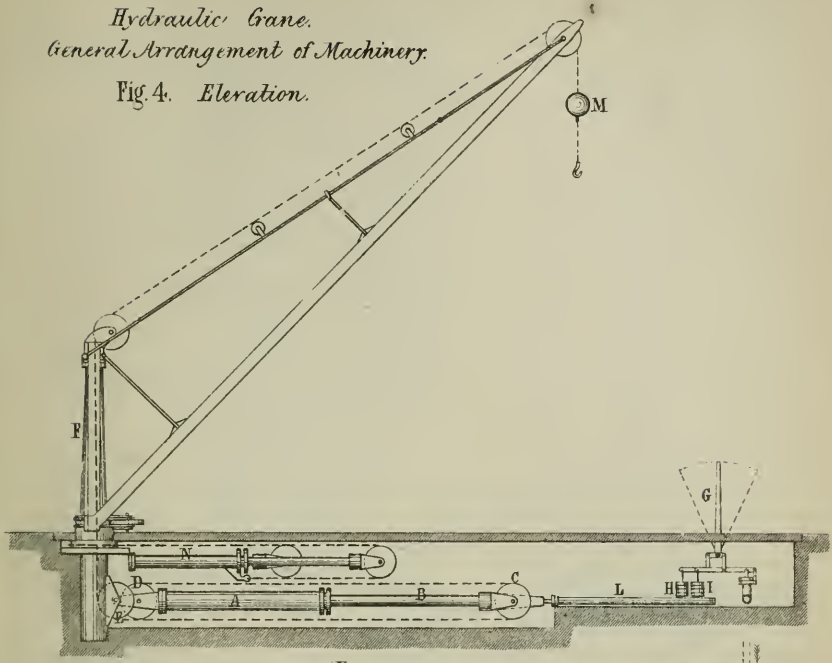
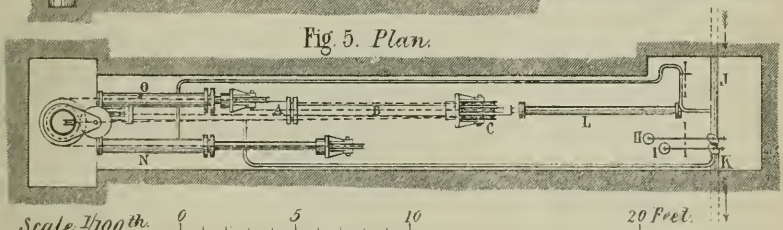


Fig. 5. *Plan.*



Scale 1/100th. 0 5 10 20 Feet.

Section of Slide Valve and Relief Valves for Hydraulic Cranes &c.

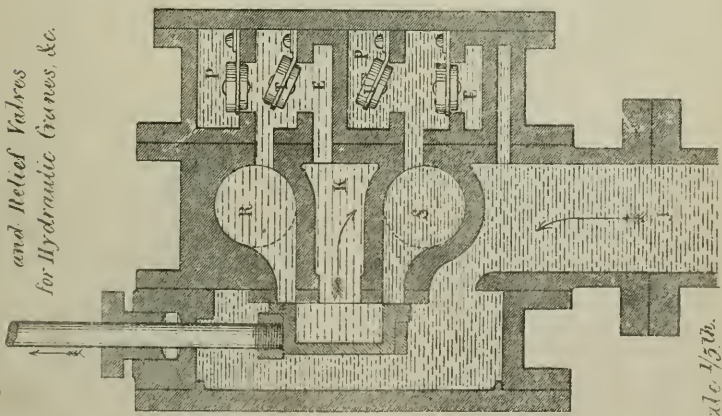
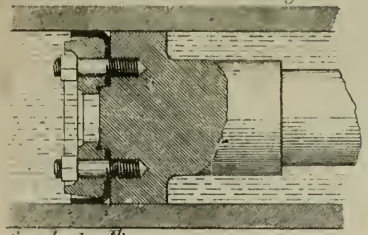


Fig. 6.

Scale 1/5th. 0 1 2 3 4 5 6 7 8 9 10 Inches.

(Proceedings Inst. M. E. 1858. Page 130)

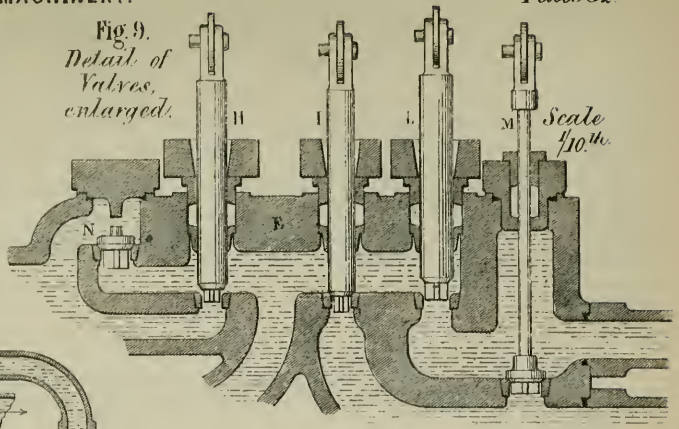
Fig. 8.
Section of Piston, enlarged.

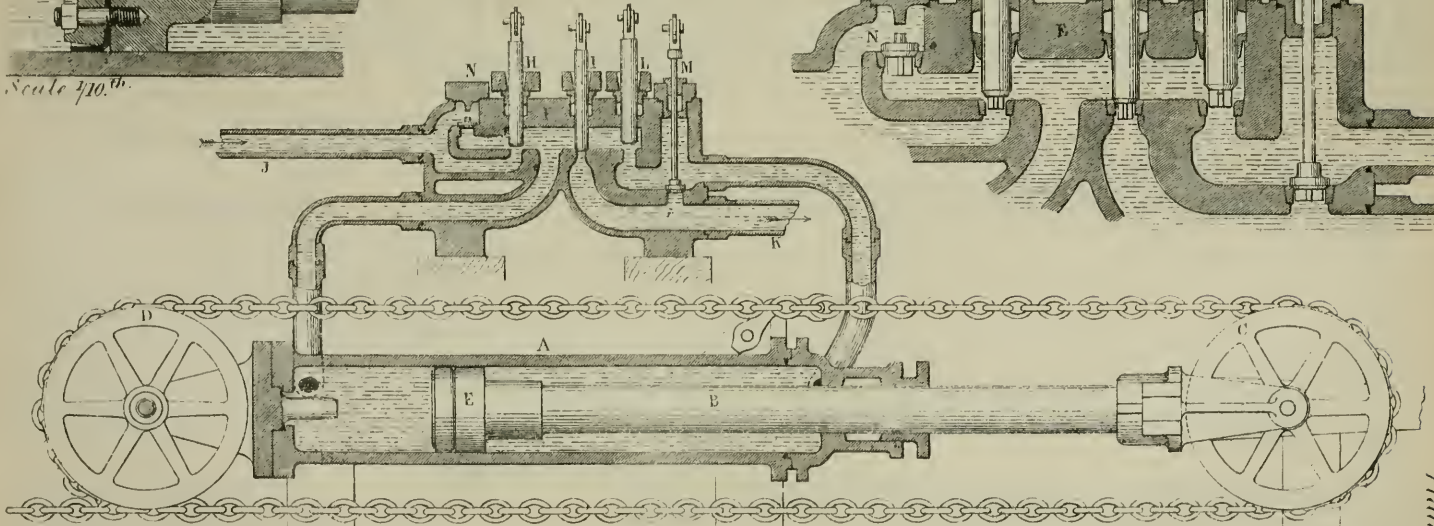


Scale 1/10th.

Fig. 7.
Double Power Hydraulic Crane.
Longitudinal Section of Cylinder and Valves.

Fig. 9.
Detail of Valves, enlarged.





(Proceedings Inst. M.E. 1868 Page 130)

Scale 1/20th.

Ins.s 12 6 0 1 2 3 4 5 Feet

Plate 32.

WATER PRESSURE MACHINERY.

Fig.10. *Elevation of Pressure Cylinders for opening and closing Lock Gates.*

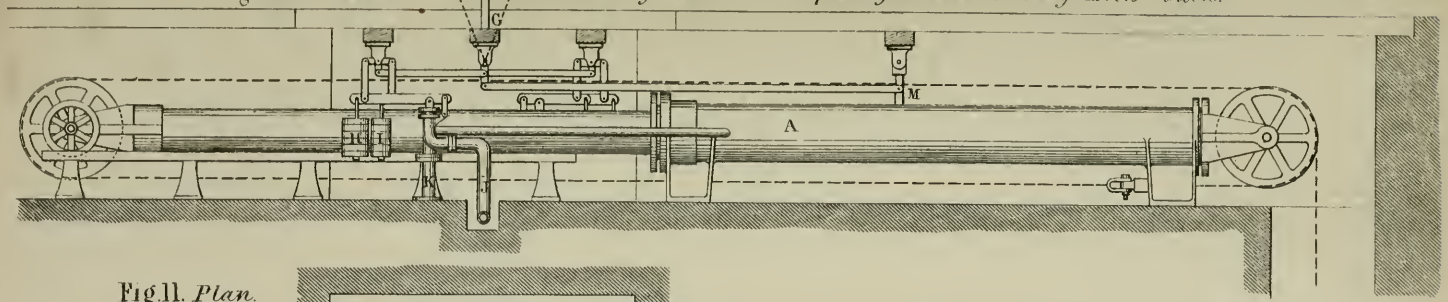
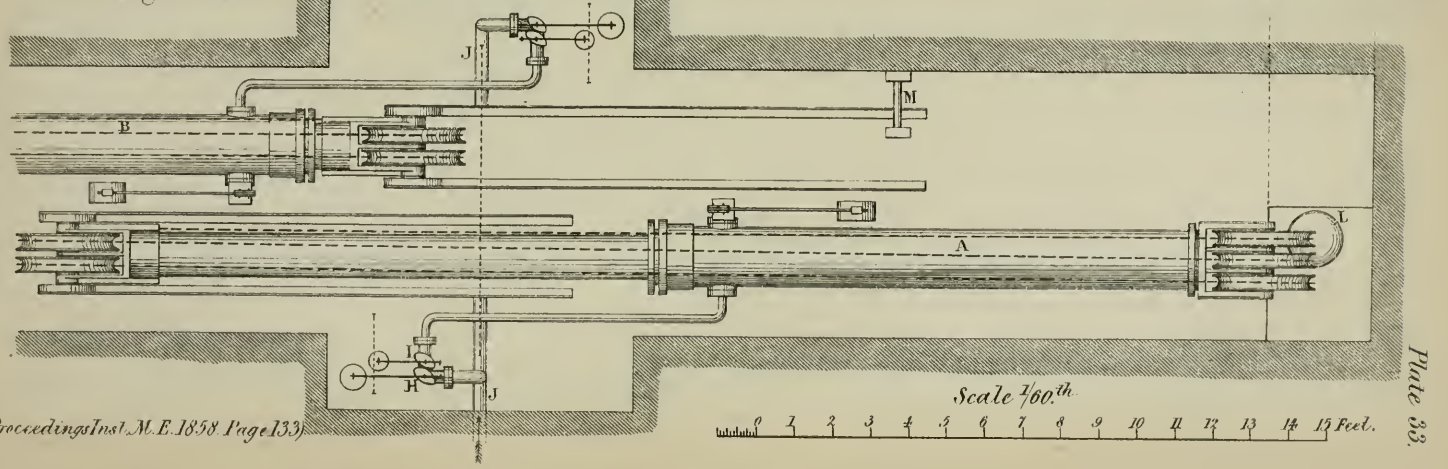


Fig.11. *Plan.*



Scale 1/60th.

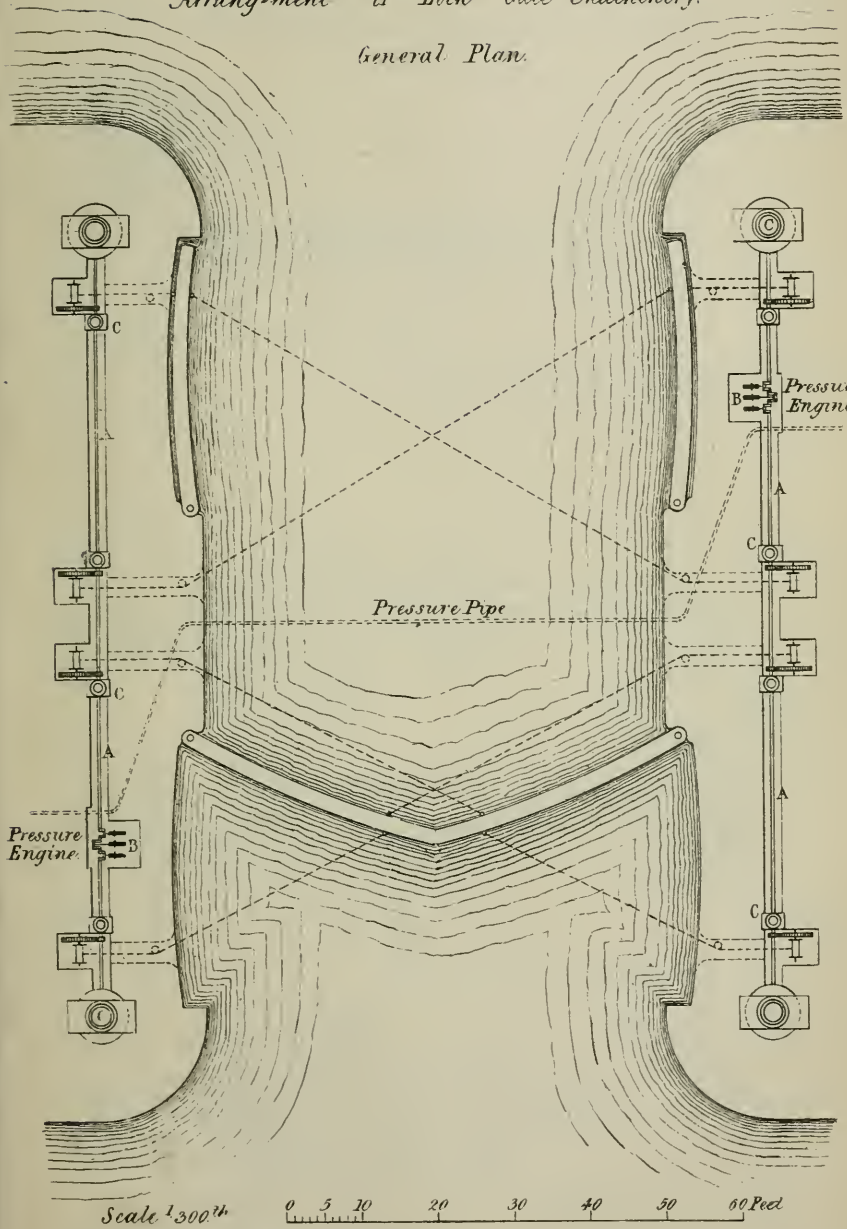
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Feet.

(*Proceedings Inst. M.E. 1858. Page 133.*)

Fig. 12.

Arrangement of Lock Gate Machinery.

General Plan.



(Proceedings Inst. M.E 1858. Page 133)

Water Pressure Engine.

Fig. 13. *Vertical Section through Cylinder and Valve Chest.*

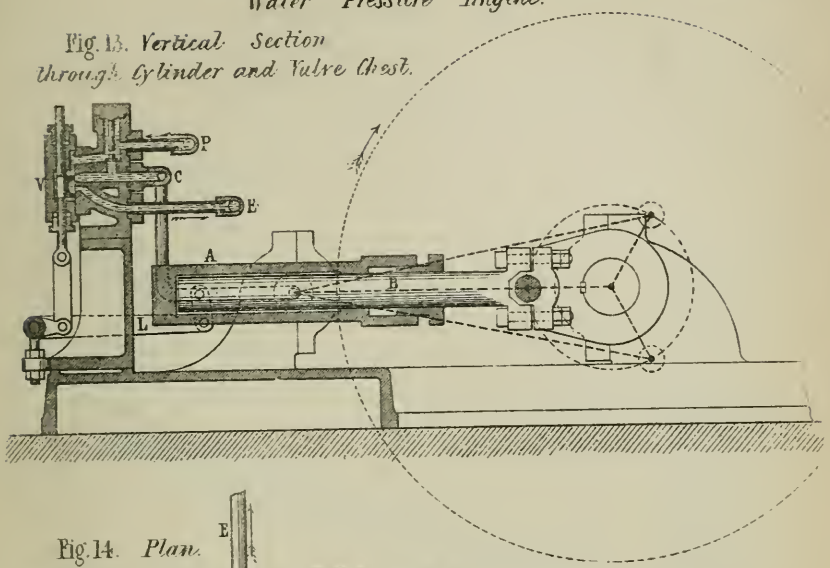
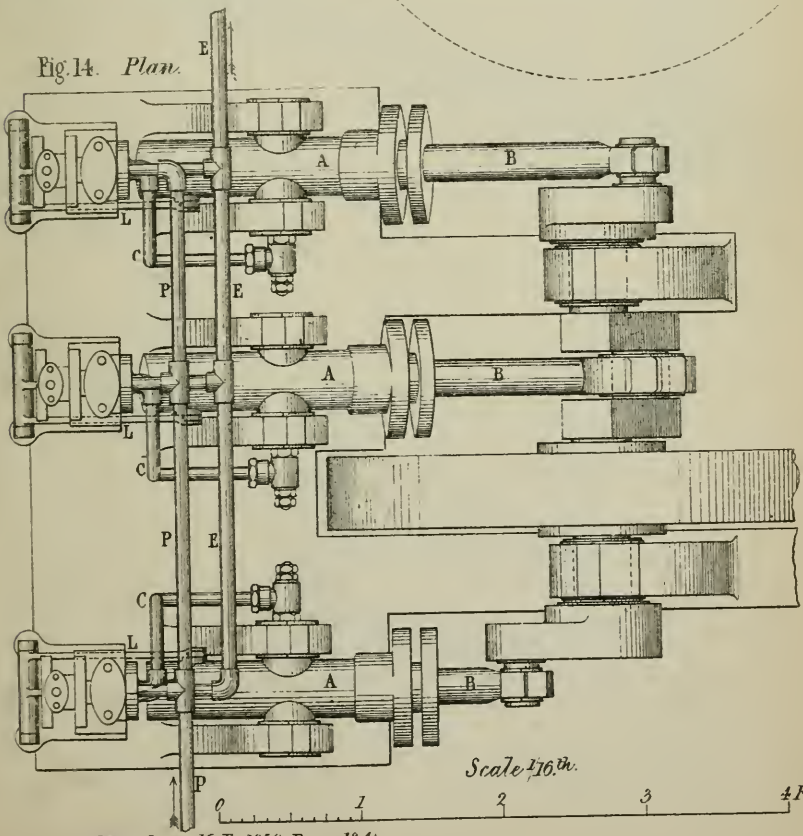


Fig. 14. *Plan.*



(Proceedings Inst. M. E. 1858. Page 134)

Granulating Tank.

Fig. 1. *Longitudinal Section.*

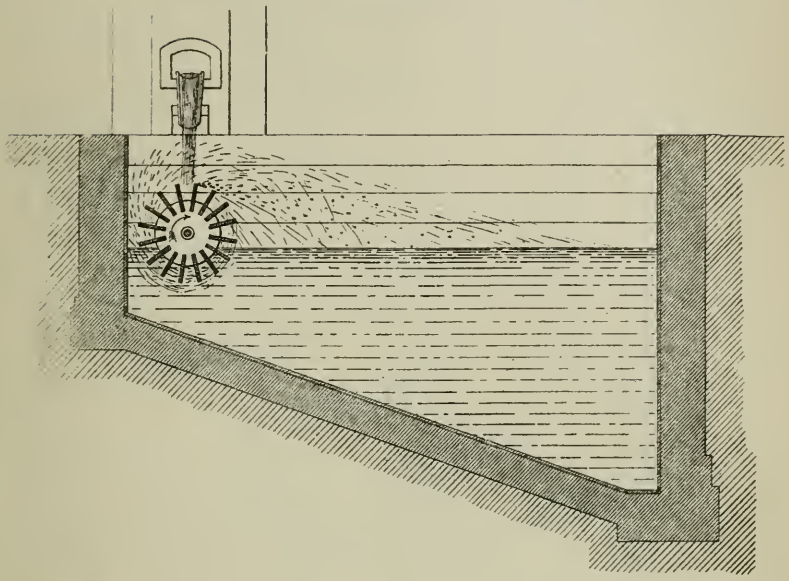
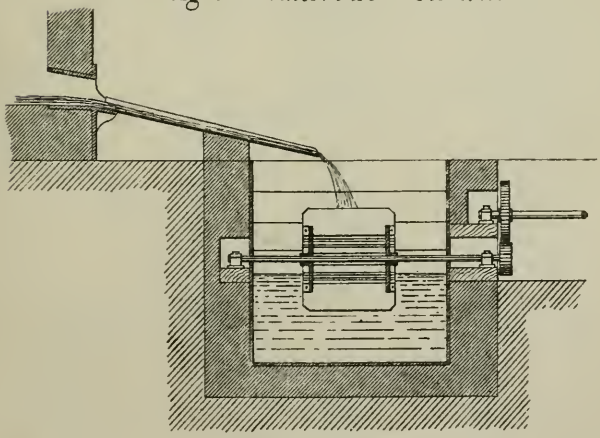


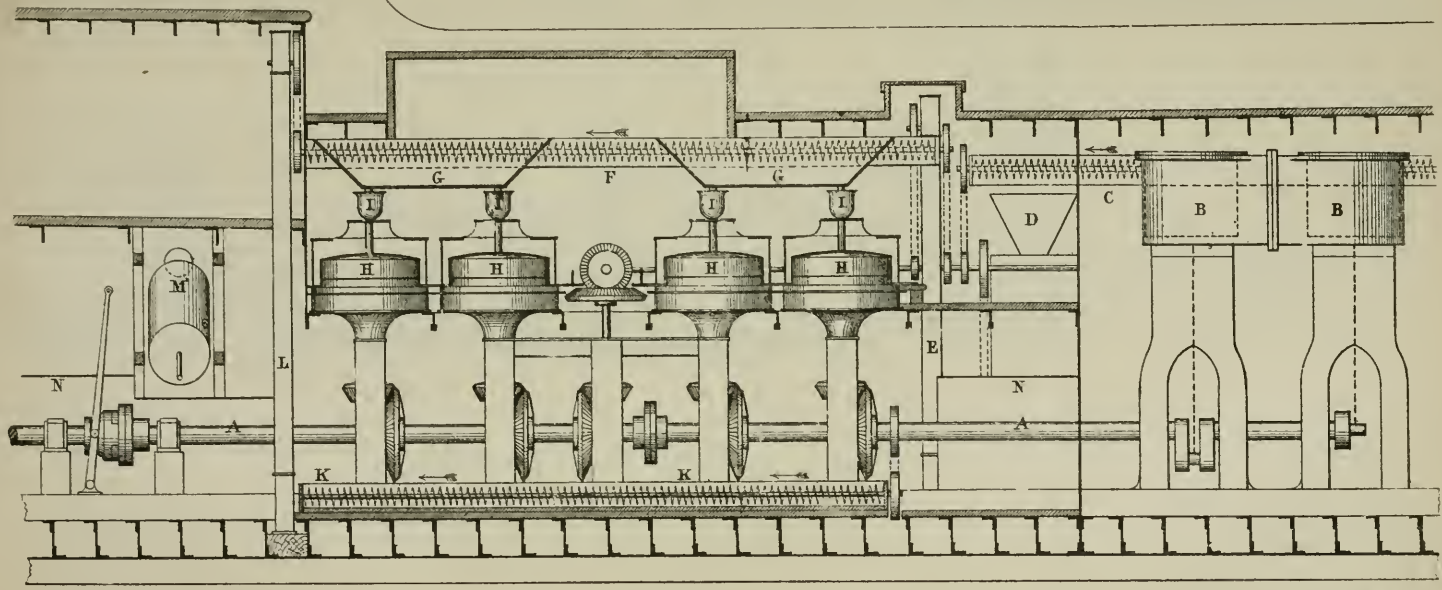
Fig. 2. *Transverse Section.*



Scale 1/60th 0 1 2 3 4 5 6 7 8 9 10 *Feet.*

(Proceedings Inst. M. E. 1858. Page 148.)

Fig 1 *Longitudinal Section.*



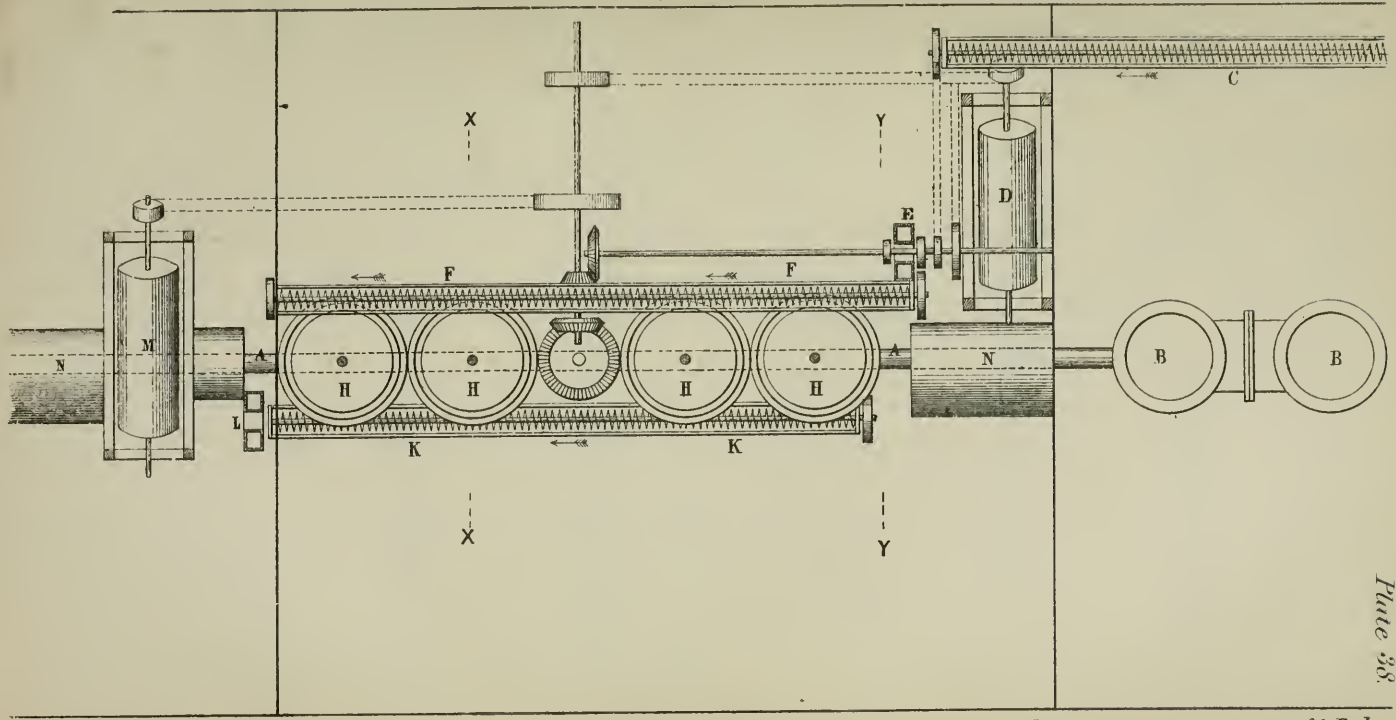
(Proceedings Inst. M.E. 1858. Page 156.)

Scale 1/80th 0 1 2 3 4 5 6 7 8 9 10 20 Feet.

Plate 37.

FLOATING STEAM CORN MILL.

Fig 2. *Plan*



Scale 1/80th. 0 1 2 3 4 5 6 7 8 9 10 20 Feet.

(Proceedings Inst. M.E. 1858. Page 156.)

Plate 38.

Fig. 3 *Transverse Section at* XX.

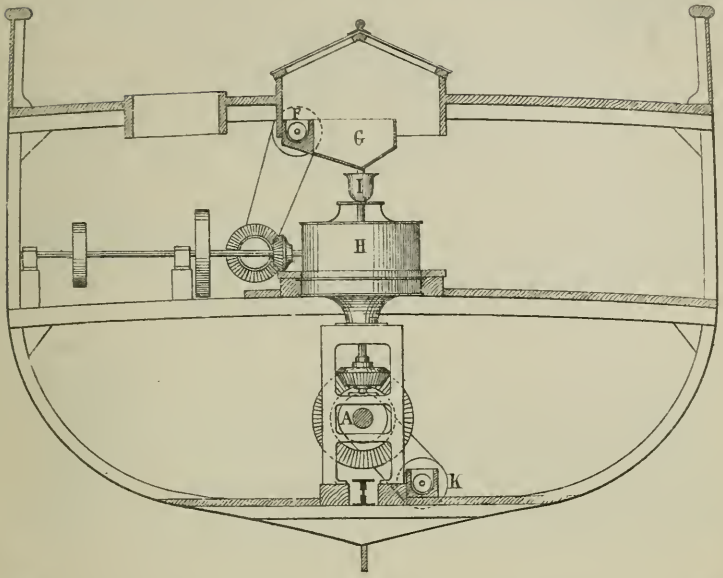
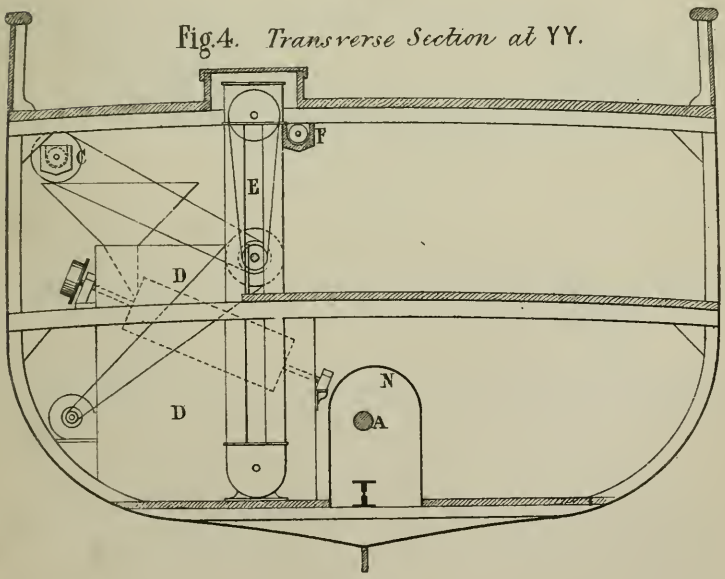


Fig. 4. *Transverse Section at* YY.



Scale 1/80th 0 1 2 3 4 5 6 7 8 9 10 *20 Feet.*

(Proceedings Inst. M.E. 1858. Page 156)

Fig. 1. *Wagon Spring with Curved plates.*

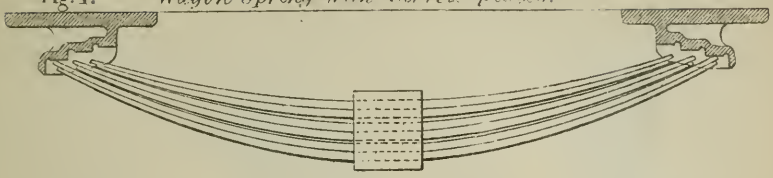


Fig. 2. *Wagon Spring with Straight plates.*

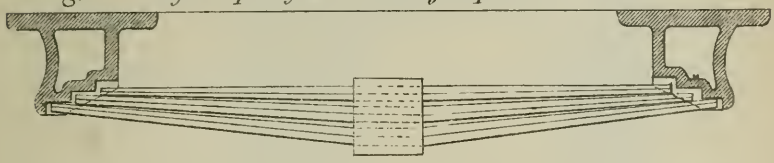


Fig. 3. *Engine Spring with Straight plates.*

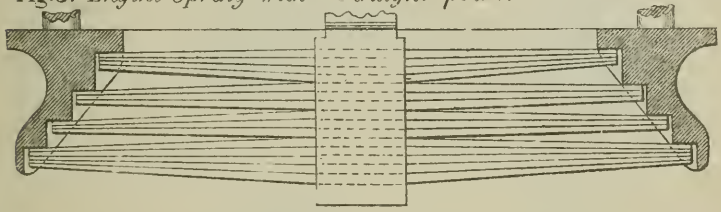


Fig. 4. *Tender Spring with Curved plates.*

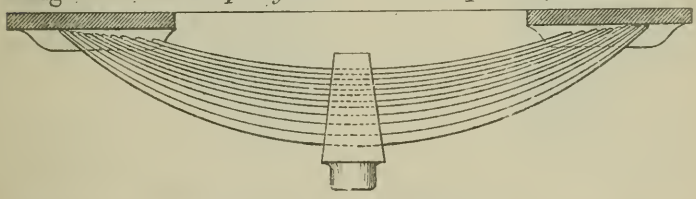


Fig. 5. *Tender Spring with Straight plates.*

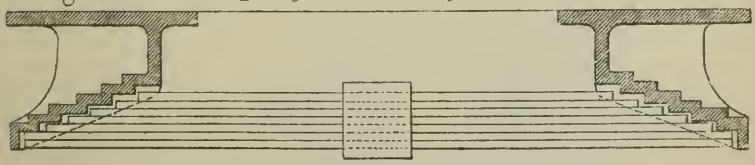
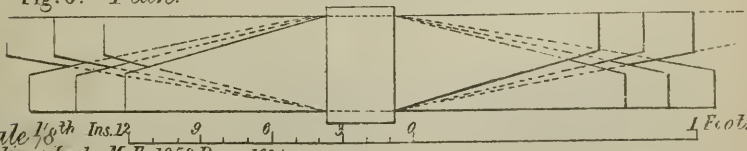


Fig. 6. *Plan.*



(*Proceedings Inst. M.E. 1858. Page 161.*)

Fig. 1. *Axlebox for Leading Wheels*

Fig. 4. *Axlebox for Driving Wheels.*

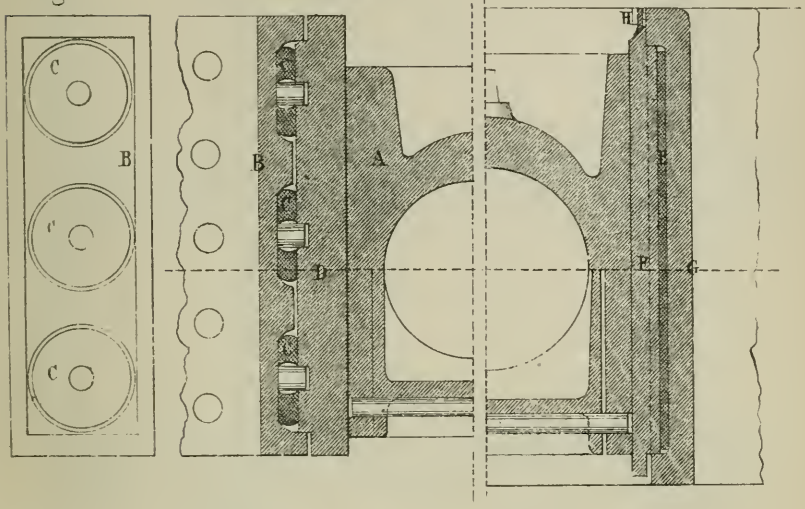


Fig. 2. *Plan.*

Fig. 5. *Plan.*

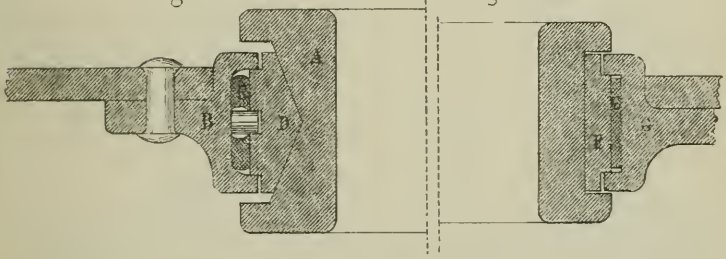


Fig 6. *Coupling Rod.*

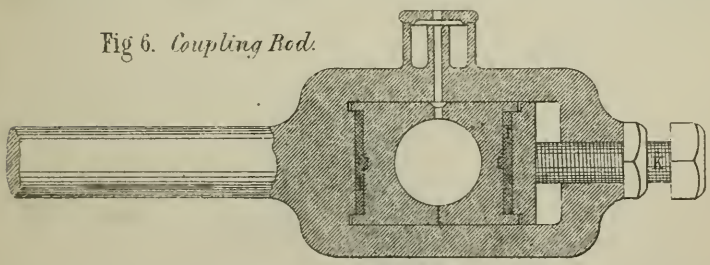
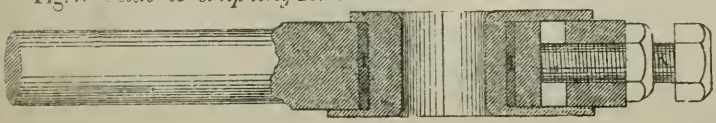


Fig. 7. *Plan of Coupling Rod.*



(*Proceedings Inst. M.E. 1858. Page 166.*)

Fig. 2.

Side Elevation.

Fig. 1. *Plan of Switch*

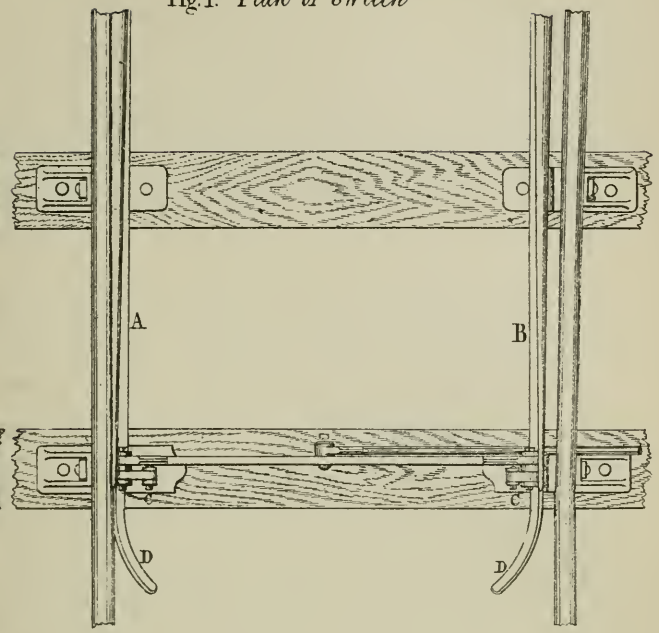
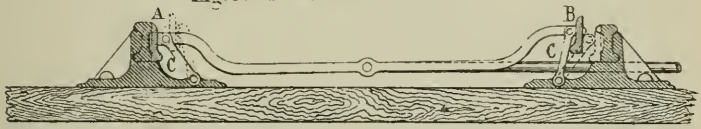
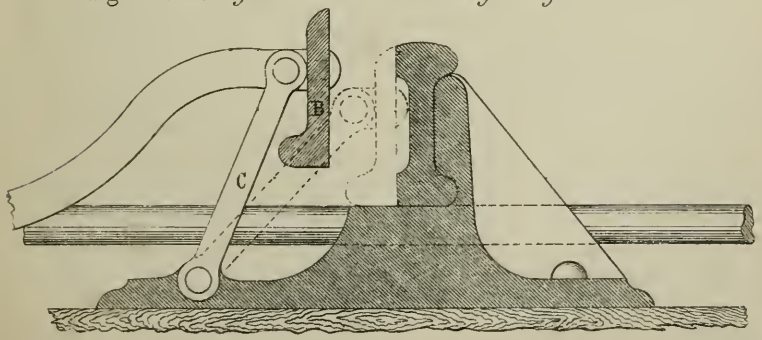


Fig. 3. *Transverse Section.*



Scale 1/24th 0 1 2 3 4 5 Feet.

Fig. 4. *Enlarged Section of Lifting Tongue.*



Proceedings Inst. M. E. 1858. Page 171)

Scale 1/6th.

The Adjourned Meeting of the Members was held in the Council Room of the Town Hall Buildings, St. Nicholas Square, Newcastle-on-Tyne, on Wednesday, 25th August, 1858; William G. Armstrong, Esq., Chairman of the Local Committee, in the Chair.

The following Paper, by Mr. Nicholas Wood, of Hetton, was read:—

ON THE IMPROVEMENTS AND PROGRESS IN THE WORKING AND VENTILATION OF COAL MINES IN THE NEWCASTLE-ON-TYNE DISTRICT WITHIN THE LAST FIFTY YEARS.

To enter into a detailed account of all those improvements connected with the present subject, that have been effected within the last fifty years, would much exceed the limits of the present paper; and the writer proposes therefore to confine himself as much as possible within the sphere of his own locality, to the coal mining of Northumberland and Durham; and to point out, in as succinct and intelligible a manner as he is able, the improvements that have been effected in that department of the useful arts which has come more immediately under his own cognisance and observation, and the inventions and discoveries connected therewith.

The subject will be divided into the following heads:—

I. Coalfield of Northumberland and Durham, its geological position, dislocations, &c.
II. Commercial character of the Coal beds.
III. Cleveland Ironstone formation.
IV. Extension of the Coal trade of Northumberland and Durham.
V. Working of Coal.
VI. Ventilation of mines.
VII. Lighting mines, safety lamps, &c.
VIII. Sinking pits, drainage, &c.
IX. Railways and steam colliers.
X. Underground conveyance of Coal.

1. *Coalfield of Northumberland and Durham, its geological position, dislocations, &c.*

A general outline plan of the coalfield of Northumberland and Durham is given in Fig. 1, Plate 43. The area of the coal beds is shown by the shaded portion, and the boundary is marked by the dotted line, extending from the sea coast near Warkworth at the northern extremity, along the western margin of the coalfield for a length of about 50 miles to the Auckland valley; and then trending along the southern boundary eastwards to Redworth, where the coal beds become covered by the overlying magnesian limestone beds; the breadth of the coalfield generally being about 20 miles, and the length along the sea coast 60 miles. All along the western margin of the coal measures they rest upon the millstone grit of the carboniferous series, and crop out to the surface throughout the entire extent above described, the beds rising greatly westwards. At or near Redworth the coal measures are met by the overlying magnesian limestone, which reposes unconformably upon them, and continues all along the southern margin of the coalfield to the sea, and for a considerable distance northwards, as shown upon the plan by the dotted line. The magnesian limestone rests upon the coal measures throughout the entire south-eastern part of the county of Durham, in a triangular shape; the base of the triangle extending eastwards about 17 miles, from Redworth to Castle Eden, and the apex running into the sea at Tynemouth, at about 21 miles distance northwards. The southern boundary of the coalfield is not clearly ascertained, owing to the overlying limestone; but, as shown on the plan, the collieries of Trimdon, Castle Eden, and several others, have been worked near the southern margin of the upper beds. How far the lower beds extend southwards is not yet ascertained. The upper beds at Trimdon, Wingate Grange, and Castle Eden, rise southwards to the magnesian limestone; but they dip eastwards towards the sea at Castle Eden, Shotton, Seaham, and Monkwearmouth; while from Harton to Hartley they rise towards the sea; and again at the northern limit at Warkworth they dip towards the sea. It is therefore not yet known to what extent the coalfield reaches toward the south-east, nor how far into the sea in the eastern portion south of the Tyne.

The lower beds of the coal measures crop out to the surface and are level with the sea at the extreme northern limit; but the line of outcrop of the measures rises gradually as they proceed west and south, until at the south-western extremity the coal measures crop out to the surface about 300 feet above the sea level. Generally the dip of the beds is at right angles to the line of outcrop of the coal, but not entirely so. The greatest depression of the beds is somewhere in the neighbourhood of Sunderland, and from this point they rise northwards, westwards, and to the south-west, so that the centre of the basin is at or near Sunderland; and from this point northwards the beds again rise towards the sea, and from Castle Eden westwards they rise to and are cut off by the nearly horizontal deposit of the magnesian limestone.

Fig. 2, Plate 44, is a section of the coal measures taken westwards from Tynemouth, in the direction marked T W on the plan. This section shows the point of greatest depression of the coal measures in the neighbourhood of Percy Main, from whence the beds rise eastwards to the sea; westwards from Percy Main the beds rise towards the west, and the High Main coal crops out a little to the north and west of Newcastle. The lower beds then become the seams worked, which rise gradually towards the west, meeting with the great 90 Fathom dyke between Blaydon and Ryton Woodside, by which they are thrown down, a gradual rise taking place westwards until they crop out to the surface at Hedley Fell.

The sandstone of the millstone grit then appears; but it is a fact of some importance in a geological point of view that the coal beds do not terminate here. The surface of the ground rises westwards along the line of the 90 Fathom dyke, which runs from this place nearly westwards until it reaches the great Penine fault at the base of the Tindale Fell hills in Cumberland and abuts against the red sandstone of the Carlisle plain, as shown in the section Fig. 3, which is an extension of the section Fig. 2, drawn to a smaller scale. In several places along the line of this dyke and immediately on the north side of it there are small detached coalfields, from 1 to 2 miles in length parallel to the dyke, and about $\frac{1}{2}$ mile in width, as at Stublick, Coanwood, and Hartley Burn. There are three or four beds of coal,

and they are generally of the same quality as the lower beds at Hedley Fell. It is a curious fact, as regards the deposit of coal and its subsequent denudation, that these small tracts of coal should exist at so great a distance from the great field of coal, the most westerly at a distance of nearly 30 miles: and it is a still more curious fact that on the south side of the 90 Fathom dyke there are no workable beds of coal in the limestone beds of Alston Moor, Tindale Fell, &c.; whereas on the north side in those beds, and immediately adjoining the dyke, there is an excellent bed of coal nearly 4 feet thick, called the Talkin seam, which is worked on the north side of Tindale Fell, and also at Blenkinsop, where it is upwards of 5 feet in thickness.

In Fig. 4, Plate 44, is given a section of the carboniferous strata taken northwards nearly parallel to the sea coast from Tynemouth to Berwick-on-Tweed, in the direction marked T N on the plan Plate 43, showing the regular coal measures resting on the millstone grit, then the great beds of the mountain limestone, and lastly the beds of old red sandstone, forming the great deposit of old red sandstone of the vale of the Tweed, which with intervals of grauwacke beds continues up the Tweed to Jedburgh and Hawick, and from thence westwards in occasional patches until it joins the red sandstone of the Carlisle plan at Cannoby. CC are the coal measures and their accompanying beds of sandstone and shale: P is the millstone grit formation: R the mountain limestone formation, with its associated beds of shale and sandstone: S the old red sandstone of the Tweed, forming the lower portion of the carboniferous series with the coarse conglomeratic red sandstone at the bottom, sometimes reposing against and sometimes resting upon the grauwacke and schist hills U of the south of Scotland: V in Fig. 3 is the red sandstone of the Carlisle plain. At the extreme northern and eastern limit of the coal measures at Warkworth, the millstone grit and limestone beds of the mountain limestone series rise out successively along the line of the coast, until they meet the almost vertical beds of the grauwacke slate formation at or a little to the north of Berwick, against which they repose: the old red sandstone beds at the bottom of the carboniferous series resting against the vertical grauwacke beds, in all the sinuosities of these rocks almost along the entire base of this formation from Berwick into Cumberland.

In some parts of the district masses of basalt exist to a considerable extent; and in the middle almost of the limestone beds a stratum of basalt is interposed called the "Whin Sill," shown at X in the sections Figs. 3 and 4. The overlying masses of basalt Z at Dunstanburgh and elsewhere seem to have been the outpouring of the basalt from dykes of that rock in the neighbourhood of those patches.

The great Penine fault, shown at Y in the section Fig. 3, which runs almost at right angles to the line of the base of the grauwacke hills, runs southwards along the western face of the escarpement of the carboniferous hills of Cumberland and Westmoreland, and forms a line of separation between the evidently upheaved beds of those hills and the horizontal beds and plain of red sandstone of Carlisle, &c. All along the base of the grauwacke hills in the north of Northumberland and south of Scotland, the old red sandstone and lower beds of the mountain limestone are not much elevated above the level of the sea; the great elevation of these beds is more towards the south-west along the eastern side of the great Penine fault: and the position of the beds of this formation, as shown in Fig. 4, would rather indicate that they have not been much disturbed, if at all, by the protrusion of the grauwacke hills; and that the latter hills were a previous elevation, and the deposit of the carboniferous rocks a subsequent deposit. The great Penine fault appears on the contrary to have been formed probably by subterranean force acting from below, elevating the mountain limestone and coal formation along the south-western extremity of this formation, on the east side of the Penine fault, as shown in Fig. 3: and it is a somewhat curious question whether the same causes have not elevated the more recent beds of the magnesian limestone likewise; for though these beds do not repose conformably upon the coal measures, they rise considerably from the sea in a south-western direction.

Fig. 5, Plate 45, is a section of the coal beds and superincumbent magnesian limestone taken southwards from Tynemouth to the southern extremity of the coalfield at Castle Eden, in the direction marked T S on the plan Plate 43; showing that the magnesian limestone beds M repose unconformably on the coal measures throughout their extent from Tynemouth southwards, and showing

also the basin shape of the coal measures. This section is nearly parallel to the sea coast, being taken in almost a direct line from Tynemouth to the Castle Eden colliery. Interposed between the magnesian limestone and the upper beds of the coal measures is a bed of marly sand O, sometimes nearly 100 feet in thickness, containing occasionally vast feeders of water and presenting formidable obstacles to the sinking of pits through that stratum.

The principal Dykes in the coalfield are shown upon the general plan Plate 43; the Slip Dykes or Faults, where the strata are simply thrown up or down, are indicated by full black lines, the amount of elevation or depression being given in each case; and the Whin Dykes, formed by the injection of a wall of volcanic matter, are indicated by dotted black lines.

A remarkable slip dyke is shown on the plan crossing the coal measures in a somewhat south-western direction, and called the "90 Fathom Dyke," along the line of which the strata are thrown down 90 fathoms or 540 feet on the north side. The down-throw of this dyke is not however always to the same extent; for in some places the strata are depressed nearly 1200 feet. It is very clearly defined to be a slip dyke of depression at Killingworth: for taking a line northwards from Long Benton to Killingworth, about $1\frac{1}{2}$ miles distance, the coal beds to the south of Long Benton and to the north of Killingworth rise very regularly and gradually towards the north, lying about 360 feet below the surface; while between these two places where they cross the dyke they are depressed on the north side about 1200 feet. Also the rise of the beds from Long Benton continues regularly northwards to the dyke, until they are about 270 feet from the surface; while on the north side of the dyke the coal has been worked about 1380 feet deep, rising rapidly from the dyke until it again assumes its regular northerly rise at 300 or 360 feet from the surface near Killingworth. It is also worthy of notice that this dyke runs through the millstone grit and limestone beds across the entire series, and terminates at the Penine fault at the base of Tindale Fell in Cumberland, throwing down the regular coal measures on the north side of the dyke and producing

small detached basins on that side as far west as Hartley Burn in Cumberland. At this place, as well as at others along its course where the coal has been worked, it is known that the coal beds dip rapidly towards the dyke on its northern side, showing it to be a dyke of depression.

Another remarkable dyke in this coalfield is a basaltic dyke called the "Hett Whin Dyke," shown on the plan Plate 43, running across the entire extent of the coal measures, from Easington on the sea coast to near Witton-le-Wear on the west. This is a true basaltic dyke, which extends into the mountain limestone measures on the west; and likewise cuts through the more recent uncomformable magnesian limestone beds near the coast, as shown in the section Fig. 5, so that it must have been formed subsequent to the deposit of the latter beds.

There is another very curious circumstance connected with this coalfield. It will be observed on the plan, Plate 43, that between Durham and Newcastle-on-Tyne, or rather between the river Wear near Durham and the river Tyne near Newcastle, two nearly parallel dotted lines are laid down; these represent an alluvial deposit to the depth of 160 feet. This is in fact what appears to have been an ancient river between those places, the depth of which has apparently been about 160 feet below the present high water level of the sea. All along the course of this river the deposit exhibits all the appearances of a wash or strong current: all the sand, gravel, and boulders of a river are found, the latter of considerable size and worn almost perfectly round; and the depth increases from Durham to the Tyne. This is certainly a curious circumstance, and would almost imply that the elevation of the mountain limestone and coal beds to the west by the same causes which produced the Penine fault had been accompanied with a depression of these beds on the east; and that the coal measures along the line of this now subterranean river bed had been depressed after their deposition and consolidation, and so lowered the bed of the river below the present sea level. The rapidity of the water of this ancient river is shown by the soft strata of its sides being greatly abraded all along its course.

There are several beds of coal in the Northumberland and Durham district, the details of which are given in various published works. The following are the most important, and are those at present worked in some or other of the localities:—

1.	High Main seam (Tyne)	6 feet thick.
2.	Five Quarter (Wear)	3½ „ „
3.	Main (Wear)	5 „ „
4.	Maudlin (Wear), or Bensham (Tyne) . .	5½ „ „
5.	Low Main (Wear), or Yard (Tyne) . . .	3½ „ „
6.	Hutton (Wear), or Low Main (Tyne) . .	4½ „ „
7.	Harvey (Wear), or Beaumont (Tyne) . .	4½ „ „
8.	Busty Bank (Tyne)	5 „ „
	Total thickness . . .	37½ feet.

As this paper is intended to give only a very general description of the coalfield, the details or precise thickness of each seam are not attempted to be given. In different localities all the seams vary in thickness, neither are they all workable in the same locality. They are likewise in some localities divided by bands of stone which increase in thickness, and thus other seams are formed having specific names; and in some instances the same bed of coal has different names in different localities. Thus the Hutton seam on the Wear is called the Low Main on the Tyne and in the steam coal district; and again the Low Main of the Wear is called the Yard coal of the Tyne. It would be a great convenience if a general nomenclature could be established throughout the entire district; for it requires a reference to the works especially devoted to those details in order to identify what seam is meant by a particular name.

In the appended Table I. is given an entire section of the coal measures at the Seaham and Seaton pits, where they are at nearly their greatest depth from the surface or near the bottom of the basin, giving the strata as far down as to the Harvey seam. The Harvey seam however is not the lowest in the series; a sinking has recently been made by the writer at Black Boy colliery to a seam of clean coal which is 360 feet below the Harvey seam and about 5 feet thick, identical with the Woodhouse Close and St. Helen's seam in the Auckland district, and supposed to be the lowest workable seam in the district.

In Table I. the Low Main seam is not in its proper position, in consequence of a slip dyke crossing the shaft. Table II. gives a section of the sinking of the adjoining colliery at Murton, from the Main to the Hutton seam, showing the regular stratification free from dykes.

II. *Commercial character of the Coal beds.*

The general character of the coal found in the Newcastle coalfield is that of a bituminous coal, yielding large quantities of gas, making excellent coke; but in some parts of the coalfield it is open burning, slightly if at all coking, and thus forming steam-engine coal. Without going into the chemical nature of the different sorts of coal, which has been fully described in other works and which it is foreign to the purpose of this paper to give in detail, it may be stated that in a commercial point of view there are four distinctive varieties of coal, namely:—Household-Fire coal—Gas coal—Coking and Manufacturing coal—and Steam-Engine coal.

A list has already been given of the different beds of coal occurring in the Newcastle district. As regards their commercial character, the first four beds, namely the High Main, the Five Quarter, the Main, and the Bensham seams, are essentially household-fire coal, in some localities excellent in quality, in others deteriorating to inferior quality; they never become first rate, although occasionally nearly so. These beds, though varying in quality, substantially retain their character of household coal; they are too carbonaceous for a good gas coal, too bituminous for a good steam coal, and do not possess the pure quality or other characteristics of a fine household or of a good coking coal.

The next bed in succession, namely the Low Main of the Wear or the Yard coal of the Tyne, probably retains its character throughout the entire district most uniformly of all the beds. In the extreme southern portion on the Wear it is a hard bituminous open burning or carbonaceous coal, adapted in some respects as a household coal, and likewise as a steam or manufacturing coal, and used for these purposes; not first rate in any of its qualities, but preferred as household coal to some others, from being very hard and not liable to break into small

coal; and hence it is extensively used for foreign export as household coal, though it produces a considerable quantity of white ashes. Its carbonaceous property and its open burning adapt it for steam engine purposes, although somewhat too bituminous: it is less bituminous in the north of the coalfield and in that locality forms a better steam coal.

The next bed is the Hutton seam; which is perhaps the most important and certainly, commercially considered, the most peculiar of any of the beds. In the southern part of the coalfield on the south of the Wear it forms the most superior household coal, namely the Hetton, Haswell, and Stewart's Wallsend coal; and is perhaps the most perfect and best household coal in existence, leaving no residue whatever when in perfection. Proceeding north and west from the Wear it becomes more friable or more tender, though still bituminous: and at Pelaw Main, Pelton, Springwell, Heworth, and Felling, it forms the best coal for gas purposes in the coalfield. It does not yield such a large quantity of gas as the Cannel coal of Lancashire, but in some other respects it is superior; and at the present time upwards of two million tons of it are annually exported for gas purposes. Towards the north of the coalfield the quality of this bed deteriorates; it becomes less bituminous, more carbonaceous, and less pure; but in the extreme north division of the Tyne and in the Cramlington and Hartley district it becomes the best steam-engine coal in the district, burning quite freely and open, leaving no clinkers and scarcely any ashes, and not being at all of a coking or bituminous character in the fire. It will be seen therefore that the Hutton seam of the Wear or the Low Main of the Tyne, the same bed of coal, assumes in the different districts the several characters of the best household coal, the best gas coal, and the best steam-engine coal of the coalfield.

The next two beds, namely the Harvey and the Busty Bank seams, possess the property of coking, and are those now so extensively made use of for locomotive engines. The upper bed partakes of the qualities both of a gas coal and of a coking coal, and is used for both purposes: but it is not of first rate quality. But the lower bed is of excellent quality as a coking coal, burning quite clean on the firebars of the locomotive engines, and leaving no scoria whatever.

There are also two or three other beds of coal in the western part of the coalfield, of the same quality of coking coal, which seem to result from a division of the beds previously enumerated, or to be thin portions of the upper beds which become workable near the outcrop of the lower beds.

III. *Cleveland Ironstone formation.*

Connected with the commercial and also the geological features of the Northumberland and Durham coal district is the discovery of the great ironstone formation of Cleveland: and as this deposit has operated and is likely hereafter to operate so powerfully upon the commercial interests of the Durham coalfield, it may be desirable to give a more detailed description of it.

A section is given in Fig. 6, Plate 45, showing the position of the ironstone beds of Cleveland, taken south-eastwards along the coast to Staiths, commencing at a point 13 miles south-east of the Castle Eden extremity of the former section in Fig. 5. The following is the order of superposition in the section Fig. 6 :—

Lower shale, and sandstone oolite.
Dogger or inferior oolite series, and "Top seam" of Cleveland Ironstone.
Upper lias shale, and its divisions.
"Main seam" of Cleveland Ironstone.
Marlstone series.
Lower lias shale.
New red sandstone.
Magnesian limestone, red marl, and sand.

The first six beds of this series are exposed in various localities along the coast from Staiths to Whitby. On the lower shale and sandstone oolite bed reposes the great oolitic limestone, covered by the upper shale and sandstone, then the cornbrash limestone, Kelloways rock, Oxford clay, calcareous grit, coralline oolite, gault, red chalk, and then the great chalk deposit; all of which are exposed along the line of the coast from Whitby to Flamborough Head.

It will thus be seen that the two seams of ironstone exist in the lias and oolitic formation; and it is somewhat singular that though these seams are exposed for several miles in the high cliffs along the coast, they should have remained for so many centuries undis-

covered as deposits of any commercial value. It is stated by Mr. Marley that "ironstone had been worked in Rosedale so far back as 1328: an inspeximus dated at York, Feb. 26, 2nd of Edward III. (1328), recites the grant of a meadow called the Baggathwaite to the nuns by Robert de Stuteville, given by that family in 1209; in which grant it appears that ironstone was worked in Rosedale at an early period." Professor Phillips, in his Geology of Yorkshire in 1829, states that ironstone abounds on the coast and has been formerly shipped in large quantities to Newcastle; and he designates the ironstone beds as "dogger bands." In 1790, 1798, and 1800, it had been represented to Mr. Wharton of Skelton that ironstone existed on his estate, but it appears not to have been attended to. In 1811 Mr. Ward Jackson of Normanby Hall had samples sent to Newcastle, the answer to which was that it was good for nothing. In 1827 or 1828 Mr. Bewick inspected the coast and reported to Mr. B. Thompson that ironstone existed: and on the publication of Professor Phillips' work Mr. Charles Attwood directed his attention to the subject. After this period and about 1830, attention having been drawn to the subject, various parties opened out ironstone for trial: but it was not until 1836 and 1838 that any quantity was worked, and unquestionably Messrs. Bolckow and Vaughan have the credit of opening out this ironstone and testing it on a large scale; and it is satisfactory to state that they have reaped the benefit of their enterprise, and are the most extensive ironmasters of the district, having now 16 blast furnaces.

The section in Fig. 6 shows that there are two distinct seams of ironstone; namely, the "Top seam" at nearly the top of the upper lias shale, and the "Main seam" at the bottom of the same deposit: the thickness of the lias shale varying in different localities. In Tables III to VI (appended) are given sections of the strata in different parts of this deposit, to show the extent and position of the seams of ironstone and the different concomitant strata.

Table III gives a section of the strata at Eston Nab near Redcar, near the commencement of the section drawn in Fig. 6, Plate 45; at the northern extremity of the lias formation, showing the thickness and position of the ironstone seams.

Table IV gives a section taken near Staiths, the southern extremity of the section drawn in Fig. 6, Plate 45, about 16 miles south-east of the section given in Table III; the section in this case passes through the Main seam of ironstone only, the Top seam being here removed by denudation, as shown in the section drawn in Fig. 6.

Table V gives a section of the strata in Rosedale Cliff at Rosedale Docks, on the coast about 2 miles south-east of the section in Table IV.

Table VI gives a section in the vale of the Esk near Whitby, the extreme southernmost part of the district, about 12 miles further south-east beyond the section in Table V, being about 30 miles south-east of the first section at Eston Nab near Redcar in Table III.

It may be stated generally that the Top seam is in the greatest perfection in the southern part of the district, as in Table VI; and the Main seam in the northern part, as in Table III. Thus in Table III, which gives the section in the northern part of the district, the Top seam is only 1 foot 3 inches thick; while in the southern part it increases to 4 feet 7 inches thick in Table V, and 12 feet thick in Table VI. On the other hand, the Main seam in the northern part is 19 feet 6 inches thick in Table III, and 13 feet 10 inches in Table IV; while in the southern part it is only 8 feet 7 inches thick in Table V, and 10 feet 8 inches in Table VI: though in Table VI there is also a laminated ironstone band 6 feet thick above the Main seam, and a band 7 feet 3 inches thick below the Main seam; but the beds are much divided by shale. It would appear therefore that though each seam varies in thickness in different localities, there is an approximate uniformity of thickness in the entire mass of ironstone at the two extremities of the district, as in Tables III and VI, though 30 miles apart.

It will be seen therefore that these two great seams of ironstone, the Top seam and the Main seam, are from 210 to 260 feet apart, extending along the line of the coast for upwards of 20 miles, and continuing beyond Whitby; and as the lias formation covers a considerable breadth of country to the west of this locality, their width is also very considerable. There is also another seam of ironstone above the Top seam, which occurs near Ingleby, and is supposed to be about

120 feet above the Top seam; this is called the Ingleby Top or Third seam, and the following is the section of it at Burton Head, at the Ingleby Manor mines:—

	Feet.	Ins.		Feet.	Ins.
Ironstone, top band	2	2		2	2
Shale					9
Ironstone		8			8
Plate or shale				1	3
Ironstone		8			8
Total thickness of Ironstone	3	6	Do. of seam	5	6

A very peculiar deposit of ironstone in the Rosedale Valley has now to be described. The valley is about 15 miles west from Whitby, and about the same distance south-east from Eston Nab near Redcar which adjoins the commencement of the section drawn in Fig. 6, Plate 45. It seems to have been scooped out of a nearly level plateau of the lias beds. The Top seam of ironstone is at a comparatively small depth from the level ground, and therefore crops out almost around the upper part of the valley. About the middle of the valley and nearly opposite Rosedale Abbey, a large mass of ironstone was discovered in a quarry in the side of the valley, and about 200 feet above the bottom of the valley. The ironstone in this quarry has since been found to be upwards of 60 feet in thickness. It is highly magnetic, and differs from the Top and Main seams of ironstone in this respect, as well as in containing no shells whatever; whereas those two seams contain large quantities of shells of the *pecten* and *avicula* species: it likewise yields a much larger proportion of metallic iron. As the quarry was in the vicinity of a slip dyke in the strata, the ironstone bed was at one time supposed to be a local deposit, the result of the dyke. To ascertain this, a drift was set away into the side of the valley and was driven 795 feet from the outcrop of the ironstone; and at the extremity the bed of ironstone was found to be 32 feet in thickness, being about the same as in other parts of the drift. At 1209 feet beyond the extremity of the drift, three boreholes were put down from the surface, one in the direct line of the drift, the other two each 600 feet from the middle hole on the opposite sides of this line and at right angles to it. The following are the sections proved in these boreholes:—

Middle Borehole.

	Feet.	Ins.
Various strata	238	3
Ironstone and shale; Upper bed	13	3
Various strata	19	6
Ironstone; Lower bed	32	0

North Borehole, 600 *feet from Middle Borehole.*

Various strata			231	6
Ironstone and shale: Upper bed				
Ironstone	4	6		
Shale	7	0		
Ironstone	3	0	14	6
Various strata			36	0
Ironstone; Lower bed			29	3

South Borehole, 600 *feet from Middle Borehole.*

Various strata			229	9
Ironstone and shale; Upper bed				
Ironstone	4	0		
Shale	5	0		
Ironstone	5	0	14	0
Various strata			30	4
Ironstone; Lower bed			32	0

The drifting and borings have proved the lower bed of ironstone to exist for 2004 feet from the outcrop, and 1200 feet in width, with as nearly as possible a uniform thickness of 32 feet, showing that it cannot be a result of the dyke, since such an extent of bed is not characteristic of a dyke, but indicates a deposit of considerable magnitude. It is throughout the whole extent magnetic: its position is below the Top seam and above the Main seam, and it is supposed that the first or upper bed of ironstone in the borings is the Top seam of Cleveland; the Main seam is found at the bottom of the valley at the lower end, but is much broken and divided and is not considered workable.

The following are given as the percentages of iron produced by the different beds of ironstone:—

	Number of Specimens.	Percentage of Iron.
Top seam	20	31·46
Main seam	50	30·97
Quarry in Rosedale	8	47·60
Drifts near Rosedale	4	43·14
Ingleby seam	9	41·14

In reference then to the subject of this paper, namely the progress made in mining within the last fifty years, we find that in the year 1800 there were only 2 blast furnaces in these two counties of Northumberland and Durham; 3 more were erected in 1828; and 6 in 1836, about which time the Cleveland ironstone came into use; and from that date to the present time the smelting of iron has rapidly increased, so much so that in 1857 there were 73 furnaces in blast, 13 in course of erection and out of blast, making a total of 86 blast furnaces. The 73 furnaces in blast are estimated by Mr. Marley to produce about 584,000 tons of pig iron per annum, requiring for this production about 3,000,000 tons of coals, 379,000 tons of limestone, and 1,690,000 tons of ironstone per annum.

IV. *Extension of the Coal trade of Northumberland and Durham.*

The rapid extension of the coal trade of these counties within the last fifty years is most remarkable. At the commencement of that period the total quantity of coals exported was about 2½ millions of tons; these were exported from the rivers Tyne and Wear, and a small portion from Hartley and Blyth. The great coalfield of Auckland was not then opened out, except a few land-sale pits: no collieries had been opened out south of the turnpike road from Durham to Sunderland: there was no Seaham harbour, no Hartlepool or West Hartlepool, no Middlesboro' harbour, and no export of coals from Stockton-on-Tees: all the Hetton, Haswell, South Hetton, and Hartlepool collieries were unopened. Since 1818 or within forty years, the ports of Stockton-on-Tees by the Stockton and Darlington Railway, and Middlesboro' by an extension of that line, have become extensive shipping ports; East and West Hartlepool by the Clarence or Stockton and Hartlepool Railway; Seaham by the Seaham line of railway; and Amble by the Radcliffe line of railway.

The following is a return of the quantities of coal in tons exported from the several ports in the counties of Northumberland and Durham in the years 1799 and 1856; showing the quantity exported to London and other ports in the United Kingdom, and also to foreign countries:—

Coals exported by Sea from Northumberland and Durham in 1799 *and* 1856.

	Year.	To London, &c.		To Foreign Countries.		Total Quantities Exported.	
		Coals. Tons.	Coke. Tons.	Coals. Tons.	Coke. Tons.	1799. Tons.	1856. Tons.
Newcastle	1799	1186720	...	114920	...	1301640	...
	1856	1978682	6898	1714668	98048	...	3798296
Blyth	1799	110478	...	337	...	110815	...
	1856	96479	...	79757	...	...	176236
Amble	1856	21228	...	37801	...	...	59029
Sunderland	1799	791213	...	10703	...	801916	...
	1856	1337538	304	700654	27747	...	2066243
Seaham	1856	652625	...	70675	101	...	723401
Hartlepool	1856	1074189	1625	488595	31473	...	1595882
Stockton	1856	11104	33	4042	503	...	15682
Middlesboro'	1856	142438	663	76531	26676	...	246308
Total Quantity Exported						2,214,371	8,681,077

The total quantities exported at the respective periods are therefore :— in 1799, 2,214,371 tons of coals; and in 1856, 8,681,077 tons of coals and coke.

Besides the above quantities of coals exported, there are large quantities conveyed along the district railways and the several railways extending from them, which did not exist in 1800 nor for nearly 20 years afterwards. The quantities of coal conveyed by railway in 1856 and 1857 as given in Mr. Hunt's report are as follows :—

Coals conveyed by Railway from Northumberland and Durham in 1856 *and* 1857.

	1856. Tons.	1857. Tons.
North Eastern Railway (omitting coke in 1856)	1753046	2554330
Newcastle and Carlisle Railway	197394	184502
Great Northern Railway	244308	164665
Total Quantity Conveyed	2,194,748	2,903,497

The following is given in the report above mentioned as the gross produce of the Northumberland and Durham collieries, about 410 in number, in 1856 and 1857 :—

Gross Produce of Northumberland and Durham Collieries in 1856 *and* 1857.

	1856. Tons.	1857. Tons.
Coals exported to foreign countries	3165112	3632211
Coke do. equal in coals at double weight to	418796	443974
Coals sent coastways	5440131	5663189
Coke do. equal in coals at double weight to	19096	22842
Coals and Coke sent inland by railway . .	2257000	2143134
Coals sent to London by railway	164534	109175
Coals and Coke used in ironworks	2298000	2432000
Colliery consumption	130000	130000
Local consumption for manufacturing, &c. .	1600000	1250000
Total Produce of Collieries	15,492,969	15,826,525

There are no means of ascertaining the entire produce in 1800: but with regard to the first six items in the above statement, the total quantity in 1799 as previously given is 2,214,371 tons; and as regards the seventh item, it has been already stated that there were only 2 blast furnaces erected in 1800, so that the whole of this item may be omitted, leaving only the colliery and local consumption, which at that period would not be more than about 500,000 tons. This gives an entire produce of about

2¾ million tons in 1800,
15½ million tons in 1856,
15¾ million tons in 1857.

The total produce of the United Kingdom has been estimated at 64 million tons in 1856 and nearly 65½ million tons in 1857; so that it appears the produce of the Newcastle-on-Tyne district is about one fourth of the entire produce of the kingdom.

V. *Working of Coal.*

The ordinary and universal mode of working the coal is by manual labour, not only at the commencement of the present century but at the present time. Attempts have been made at various times during the last fifty years to substitute mechanical power: the late Mr. George Stephenson proposed a plan and had a machine made for that purpose; but like all similar attempts when put into practice it was found to be much more expensive than manual labour, and was consequently abandoned.

A plan of coal cutting machine worked by compressed air has been recently invented by Messrs. Johnson and Dixon of Newcastle-on-Tyne, which appears to be on a principle more likely to succeed than any plan yet attempted. This machine is shown in Figs. 7, 8, and 9, Plate 46; Fig. 7 is a side elevation, Fig. 8 a plan, and Fig. 9 an end elevation. A is the flexible tube supplying the compressed air from the air pumps to the two air cylinders B. C is a toothed wheel on the main shaft for getting up the required speed of the cutter. D is the revolving cutter, projecting horizontally from the side of the machine, a section of which is shown enlarged in Fig. 10; the teeth are of cast iron chilled, and can be replaced when worn. The machine is advanced by means of the endless screws E, worked from the main shaft and gearing into worm wheels fixed on the axles of the travelling wheels F, giving a progressive forward motion along the wooden railway G laid down for the machine to travel upon. The machine is also provided with bearing wheels, for moving it about from place to place, the travelling wheels F being then removed.

The cutter D is made to revolve at the rate of 500 revolutions per minute by means of the toothed wheel C; and the machine travels forwards at the rate of 1 yard in 6 minutes, cutting the coal consequently at that rate; and the length of the cutter being 3 feet and its diameter about 5 inches, it thus makes an excavation of 1 square yard and 5 inches deep in 6 minutes. In applying the machine, the cutter drills into the face of the coal the whole of its length or 3 feet, and as near the thill or bottom of the seam as may be convenient; when the cutter is revolving rapidly, the self-acting feed motion is thrown into gear with the travelling wheels F by means of a clutch; and

the machine then travels forwards, leaving behind it a groove extending 3 feet into the solid coal and about 5 inches in height. The block of coal thus undermined is then either wedged up to prevent it falling until required to be taken down, or is brought down easily by inserting a wedge above.

This machine has been constructed and applied at Broomhill colliery, Northumberland, by permission of the owners, who granted the necessary facilities for proving its qualifications to such an extent as to show that it was capable of performing all that was expected of it. The machine is constructed with the two cylinders B of 8 inches diameter each and 12 inches stroke; the revolving cutter D is 3 feet long, the diameter to the tips of the teeth or cutters tapering from 5 inches to 4 inches at the extremity; it is grooved lengthways to receive the cutters, which slide into it and fit, the grooves being dovetailed as shown in the section, Fig. 10. The size of the machine is 6 feet length, 3 feet breadth, and 3 feet height clear. It is worked by compressed air, supplied by an air pump situated above ground or in any other convenient place; the air is conveyed to the machine by 4 inch metal pipes, terminated with about 30 feet of stout flexible india-rubber hose pipe of the same diameter, which allows the machine to travel over a certain space of ground without stoppage. The air pump consists of two cylinders, 2 feet 6 inches diameter and 3 feet stroke, making 30 revolutions per minute, and maintaining a pressure when the machine is working of from 30 to 40 lbs. per square inch above the atmosphere. The air pump was worked by a steam engine above ground at Broomhill colliery, pipes being carried down the pit to the machine; the engine was of 10 horse power, which is ample for one coal cutting machine. A large iron boiler was used as an air reservoir connected to the air pump, for keeping up a steady supply of air, and was fitted with a safety valve showing the pressure; a pressure gauge was also fixed down the pit near to where the machine was working; and it was found in practice that no loss of pressure took place between the air pump on the surface and the machine underground, the length of pipes between them being about 500 feet.

It may be necessary to explain that the most efficient mode of applying this machine is to have the colliery laid out on what is called

the "long wall" system of mining. The machine would then travel along the face of the wall, making a cut at the bottom into the solid coal along the entire length of the face. In the first opening of a mine in every case it will be necessary to have the space along which the machine is to travel excavated by manual labour; hence the advantage of its application to the long wall system, and the disadvantage of its application to the pillar and stall mode of working. At Broomhill colliery the latter mode was in operation, and the inventors have not yet been able to have the machine applied to the long wall system. The experiments made with it show that, so far as the cutting of the coal extended, it answered thoroughly the purpose intended. It is therefore of some importance to have the machine fully tried in all its bearings on the long wall system.

In reference to the cost of working the coal cutting machine, some collieries might probably have as many as six or eight machines at work, whilst smaller collieries might require but two. Taking the case of two machines being employed, the entire cost of the two machines, including a 20 horse power steam engine with air pipes &c., complete for working, may be estimated at about £1750. Then supposing each machine to work only 7 hours per day of 10 hours, leaving 3 hours for stoppages, the double shift or night and day work will give 28 hours per day for the two machines; and since each machine will cut the coal at the rate of 1 square yard in 6 minutes, the two machines will cut 280 square yards per day, or 80,360 square yards in a year of 287 working days. Taking the seam of coal to average 4½ feet thick, and 1 cubic yard weighing 1 ton, the coal cut by two machines in a year will be 120,540 tons. The cost of working for the year, including attendance on the machines and engine, coals for the engine, and repairs, would be about £1580, or a little more than 3*d.* per ton of coal worked.

Saving of coal is another advantage expected to be gained by the use of the coal cutting machine: for whilst by manual labour 14 or 15 inches height has to be curved out to bring the coal down, by using the machine only about 5 inches height is converted into small coals; and in the latter case the coal is also brought down in better condition, less shaken and in larger blocks. It is expected in consequence that

there will be a saving of solid coal of 6 inches thickness in the height of the seam, which at 2*s.* per ton the difference between the value of small and round coals would amount to upwards of £1300, and upon 120,540 tons would be nearly $2\frac{3}{4}d.$ per ton.

Having thus given a sketch of a mechanical mode of cutting coal, the writer will now describe the mode of working or abstracting the coal as practised previous to the commencement of the last half century, with the improvements which have been made during that period.

Up to the commencement of the last fifty years little improvement had been made in the mode of working coal from the earliest recorded period when coal was worked in Northumberland and Durham; and previous to that time few plans of workings have been handed down to us. Those which have been show that the general custom was to work the coal according to what is called the "pillar and stall" method, taking away as much coal as could be removed, so as to leave walls or rectangular pillars sufficient to support the roof, as shown in Fig. 11, Plate 47, in which the pillars are shaded and the passages or stalls left white. It appears to have been intended in all cases that the pillars should be made of such dimensions only as would be just sufficient to support the roof; consequently the size of the pillars varied according to the depth at which the coal lay below the surface. Moreover the early workings were near the surface requiring little ventilation, there being no inflammable gas but only carbonic acid gas or choke damp; but as the coal was worked off near the surface and the workings became at a greater depth, more ventilation was required and the air was then circulated around the workings so as to produce a continuous current; the circulation or coursing of the air in the waste or old workings being adopted somewhere about the year 1760.

It is difficult to ascertain the precise date when the working or partial removal of the pillars commenced. It appears by the old reports to have been begun in many instances by an enquiry whether the pillars left were not more than sufficient to support the superincumbent strata; and this being generally found to be the case, a system of taking away a portion from either the ends or sides of each pillar was

adopted. Subsequently a system of removing the entire pillars was commenced: it is difficult to ascertain when this plan first took place, but from reports in the writer's possession it appears that it was generally adopted soon after the commencement of last century. Where inflammable gas did not exist and where little ventilation was required, the mode pursued would be ruled entirely by the circumstances of situation, thickness of superincumbent strata and other contingencies. Where it was necessary to preserve the ventilation, another system was adopted, as shown in Fig. 11, Plate 47. The arrows indicate the direction of the currents of air, and the stoppings are shown by the black lines SS across the passages between the pillars, AA being the main doors, and DD the doors near the face of the workings. The dotted portions show the pillars which have been removed, the pillars left being shaded; from which it will be perceived that one pillar in every three is left, forming what are called the "sheth walls," or walls in which the stoppings are placed to preserve the ventilation.

At this time the safety lamp was not invented, and the only lights used were candles; and in the old workings or where gas existed, the steel mill. It was therefore absolutely necessary that the ventilation should be preserved. The expense of working the steel mill being so great that it could not be used generally (as the safety lamp is) for working pillars, no pillars could be taken away where their removal would cause the ventilation to be destroyed, and therefore the working of pillars was confined to cases similar to that shown in Fig. 11, or where in fact inflammable gas did not exist. This mode of working pillars was carried down to the period of the invention of the safety lamp. Then came this most important invention in the year 1815, which produced an entire revolution in the mode of working coal. It was now no longer necessary to preserve the ventilation so as to render all parts of the workings safe with naked lights. Pillars could be removed to any extent so far as ventilation was concerned, provided only that proper care was taken to dilute the gas where the men were working below the inflammable point, so that it should not explode within the lamp. Collieries which had been partially worked and abandoned for years as unworkable to any further extent, and in which about one third of the coal was left, were then reopened, and

the entire pillars removed; and an entirely different system or rather a variety of systems of working the coal were adopted; the only restriction necessary to be observed besides that of economical and proper working being that the immediate vicinity of where the men were working should be kept free from gas, or that it should be so diluted with atmospheric air as to render it not inflammable within the safety lamp.

It is impracticable in this paper to give all the different modes of working the coal under such circumstances. Fig. 12, Plate 48, shows generally the most usual plan, where the first working was that of leaving pillars just sufficient to support the superincumbent strata. The dotted portions show where the pillars are taken away; and here it will be seen that they are entirely removed in the progress of the working, and where removed the ventilation is entirely destroyed. The air, as shown by the arrows, is thrown upon the outer edge only of the pillar working at EE where the men are at work, and is not forced into the goaf or old workings GG. DD are the doors and SS the stoppings to throw the air upon the face of the pillar working.

At the period of the invention of the safety lamp there were large districts of pillars in the collieries of Durham and Northumberland, where gas existed, and where the pillars had been left of only adequate strength to support the superincumbent strata and to preserve the ventilation so that candles could be used; and one third if not one half of the coal was thus left. When the safety lamp was introduced, as previously stated, these pillars became workable to profit; and they have been worked generally in the mode described above and shown in Fig. 12. These pillars being only just sufficient to support the superstratum, wherever a portion was now removed, those left became insufficient for the support, especially at the edge of the workings; the effect of which was that the pillars in course of removal and those in their vicinity became crushed, and the coal rendered small; and where the extent of pillars was considerable and they were previously only just sufficient to support the roof of the mine, a general crush or creep took place, which extended throughout the whole district of the pillars. The effect of such a process generally was that the pillars were crushed into the floor of the mine, while the fire clay or

soft shale forming the floor where the coal had been removed was forced upwards; and an almost solid mass of coal and shale was formed where the pillars and spaces formerly existed, which now became the support of the superincumbent strata. Vast districts of what were called "crept pillars" were thus formed, which the use of the safety lamp has subsequently enabled us to work out, so that no coal whatever is left; the mass of shale and crushed coal in the spaces previously excavated becoming in fact the pillars to support the superincumbent strata.

It will be seen however that though large quantities of coal were thus obtained, the coal was necessarily much crushed and very friable and small; and that in the working of an entirely new field of coal such a mode was very objectionable, and under the then altered circumstances no longer necessary: consequently a great variety of modes were adopted as circumstances required. The late Mr. Buddle adopted a system of what was called "panel working"; which consisted of subdividing the coalfield to be worked into square panels or districts, around which a strong barrier of coal was left: he was thus enabled to form pillars in the first instance within the barriers, which was generally done with candles, unless a great discharge of inflammable gas existed; and then to take away these pillars with the aid of the safety lamp, while the surrounding barriers protected the other parts of the mine either from a crush or creep or from the effects of an explosion if any should occur.

Another system has been more extensively practised, which is to leave the pillars of coal in the first instance of such dimensions that they shall be sufficient to support the superincumbent strata during the operation of their removal afterwards, so that the coal is not crushed. This system is pursued generally in three different modes. First: by a system of panel working, as shown in Fig. 13, Plate, 49, leaving barriers FF between each panel; which allows of candles being used in the operation of forming the pillars as at HH, and safety lamps in their removal as at I I: the dotted portion in the latter case showing the manner in which the pillars are removed, the solid coal being shaded. Second: Fig. 14 shows another mode, which consists in carrying what is called the first working or the forming of pillars up

to the entire extent of the boundary in the first instance, and then commencing to remove the pillars ; candles being used if practicable in forming the pillars, and safety lamps as at KK in their removal. Third : in the mode of working shown in Fig. 15, Plate 50, the removal of the pillars is commenced immediately after their formation, or when the whole coal working has proceeded to such a distance that the air can be distributed so as to admit of candles being used in the formation of the pillars and safety lamps in their removal. This mode admits of the same tramroads being used in the whole coal working as in the removal of the pillars, and the same stoppings are used in both operations ; also the coal of the pillars is not deteriorated by long exposure to the air, which is involved to a certain extent by the two other modes.

These are the principal improved modes practised in working coal in Northumberland and Durham. The long wall system, which is so much used in the midland counties, is not much practised there, the beds of coal and the coal measures associated with them not being so well adapted to that mode of working as to the modes which have been described above. The details of the ventilation peculiar to these different modes of working will be more particularly described under the subsequent head of ventilation. The practical result of the improvements which have been introduced within the last fifty years has been the recovery of large districts of pillars which were condemned or which could not be worked by the means in operation at the commencement of that period ; and the adoption of the different modes of working above described has resulted in almost all the coal being obtained in the best possible condition.

VI. *Ventilation of mines.*

It may be said generally that no improvements in principle have been made in the mode of ventilating the coal mines of Northumberland and Durham within the last fifty years. The furnace has been the standard method adopted in these two counties from the earliest periods of coal mining ; and it is substantially the standard mode of ventilation employed almost universally at the present time. Attempts have been made at different periods to introduce other modes of producing currents of air in the mines, but the furnace is still considered the most efficient

ventilating power. Producing ventilation by pumping the air out of the mines was practised even in Smeaton's time : Mr. Brunton proposed the centrifugal ventilating machine : more recently the steam jet of Mr. Gurney was brought prominently before the coal owners of these counties, even by legislative recommendation : and still more recently the more perfect and to a certain extent more effective machines of Mr. Nasmyth and Mr. Struvé have been brought forward, with practical performances of considerable magnitude. . Still the furnace is the predominant power used in the Newcastle district.

Fig. 18, Plate 53, is an elevation, and Fig. 19 a plan of one of the ventilating furnaces of the Hetton colliery, which may be taken as representing the general plan used in the entire district. A is the furnace on which the coals are placed, which is 9 feet wide, the length of the bars being 7 feet; consequently the area of the firegrate is 63 square feet. The furnace is placed in the drift leading from the mine to the upcast shaft, B being the drift from the furnace to the shaft, which is generally 9 feet in width and 10 feet in height with a semi-circular arch ; the height above the furnace bars to the top of the arch is 7 feet. The furnace is generally placed at a distance of 150 to 180 feet from the upcast shaft, with the drift or passage for the air proceeding at an inclination of 1 in 6 or 1 in 4 from the furnace into the shaft. Instead of one large furnace it is usual to have two or more furnaces to each shaft. CC are two side drifts 2 feet 9 inches in width and 6 feet 9 inches in height, which are used as passages from one end of the furnace to the other, to prevent the heat of the furnace from setting fire to the coal on each side; and to allow a portion of air to pass along them, when it is not found necessary to force the whole air of the mine over the furnace. A wall D is carried up from the floor of the mine to the height of the coals on the grate, to force the air through the firebars, and to prevent the coals from falling over the end of the grate. The whole of the air therefore, except what may be allowed to pass along the side drifts, passes over the fire or through the firebars of the furnace ; and it is of great importance that the quantity of air should be so regulated that the fire may be maintained in the most intense state of action, so that the combustion of the fuel may be complete, and

no unconsumed fuel pass into the upcast shaft to produce smoke. A plate of iron is sometimes used to contract the archway above the fire to produce this effect. When therefore the fire is properly managed no smoke whatever is produced, and the whole of the heat of the coals is evolved; for it is of great importance that no smoke or heavy particles should escape into the shaft to add to the weight of the column of rarefied air, and also that the whole heat of the furnace should be imparted to the air.

The power of the furnace to produce ventilation is the difference between the weight of the column of descending air and the weight of the column of ascending rarefied air in the two shafts; a separate shaft or division of a shaft being required for the descending column and another for the ascending, forming respectively the downcast and the upcast shafts. The amount of power obtained will therefore depend on the depth of the shafts and the quantity of heat or extent of rarefaction of the ascending current, the latter being regulated by the dimensions of the furnace or area of the firegrate. At the Hetton colliery, which is an extensive one, there are three downcast and three upcast shafts; and the following Table gives the particulars and amount of ventilation produced at that colliery:—

Ventilation at Hetton Colliery.

Name of Shaft.	Area of Shaft.		Depth of Shaft.	Number of Furnaces.	Total Area of Firegrates.	Cubic Feet of Air per minute.		Temperature of Air in Upcast.	Coals consumed in 24 hours.
	Downcast.	Upcast.				Downcast.	Upcast.		
	Sq. Ft.	Sq. Ft.	Feet.		Sq. Ft.	Cub. Ft.	Cub. Ft.	Fahr.	Tons.
Minor Pits	98	145	900	4	192	206000	250000	172°	11
Elemore	100	60	840	2	96	100000	120000	162°	4
Eppleton	100	80	1044	1	54	150000	180000	162°	6
Total quantity of Air, 550 000 cubic feet per minute in Upcast shafts.									

The next consideration is the distribution of the air through the workings of the mine or the openings made in working; and this properly constitutes the ventilation of the mine.

The early working of the coal mines in the counties of Northumberland and Durham having been confined to the coal beds

near the surface, little ventilation was therefore required, since pits could be sunk with little cost; and as appears by the surface indications they have been very numerous. As the coal was worked off near the surface and the sinking of pits became more expensive and deeper, the air appears to have been conveyed to the working places only; but no attempt was made to ventilate the old workings until a comparatively recent date. The regular coursing or producing a current of air through the waste or old workings is attributed to Mr. Spedding of Whitehaven in the year 1760. As the coal was worked at greater depths and inflammable gas evolved, the distribution of the air into all the openings became a matter of necessity, and has now become a subject of deep importance. It is impracticable in the present paper to describe all the various modes now in use; the description will therefore be confined to such as will show generally the progressive advances which have been effected in this, the most important question in coal mining.

Fig. 16, Plate 51, shows the system generally practised in the early stages of ventilation. The arrows show the direction of the current of air; the black lines across the openings are the stoppings to divert the current in the proper direction, DD being the doors to allow the requisite passage for conveyance of coals and to preserve when shut the continuous course of the air. It will be seen by this diagram that there is only one current of air passing round the working, which is dispersed into three "bords" or wider openings, the three bords constituting one current; the current is taken up to successive portions of the face of the workings at UU, passed along the face of the workings, and then conveyed back alternately into the old workings or waste, and so towards the upcast shaft.

When the workings became still deeper and more extensive, and the pits more expensive to sink, it was found that a single current only, passing round the workings, experienced great resistance and necessarily became sluggish: the expedient of "splitting" the air into more than one or into several separate currents was then adopted. Fig. 17, Plate 52, shows the mode of splitting the air, which is done at L; one current going to the right towards M, and the other current to the left towards N, along the face of the workings; and afterwards being

carried around the old workings or waste as before. The arrows show the air first passing along the lower level O to the right, underneath a crossing at C, and so to L where it is split, the two currents being afterwards brought together to the same point P where they leave this district of the workings. It will be seen that the current going towards N has to travel a shorter total distance before arriving at P than the other current going towards M; it is necessary therefore so to regulate the respective resistances to the two currents that the currents shall be equal to each other. For this purpose an artificial obstruction is placed in the course of the shorter current at R, consisting of a stopping with an adjustable opening in it, which is called a "regulator" and can be closed or opened to any required extent to regulate the quantity of air which is required for each separate current. In the same manner by dividing the air into several currents, any quantity of air may be given to each separate current by means of such regulators. The resistance to the air being in proportion to the length traversed and the square of the velocity, the aggregate resistance in traversing the same total distance is of course proportionally less when the air is divided into several currents and its velocity diminished than when the whole air is in one continuous current with a greater velocity.

There is another improvement of ventilation in the plan shown in Fig. 17 over that shown in Fig. 16. In Fig. 17 the air is first carried along the entire face of the workings from L to M and N, and then taken into the old workings; this is done by stoppings being placed in the wider openings or bords at TT, and is for the purpose of supplying the fresh air to the men in the workings at UU, and taking it afterwards to ventilate the waste. The crossing at C is a viaduct carried over the main road, by which the return current of air passes over the current entering the mine. V is a small opening or "scale" to allow a small portion of air to pass along the low level.

In Fig. 12, Plate 48, is shown the mode generally adopted in ventilating the pillar and stall working. The single current is taken up to L where it is split as before, one current going to the right and the other to the left; DD are the doors, and SS the stoppings to force the air upon the edges of the goaf G or to where the men are

working at EE; from whence as shown by the arrows it is carried to ventilate the waste, the line of bord stoppings TT being the mode adopted as before to separate the air of the working places from that of the waste or old workings. C is the crossing and R the regulator as previously explained.

In Fig. 13, Plate 49, is shown the first mode of panel working previously described, the ventilation of which is accomplished as follows. The air passes up what is meant as the main railway W, underneath the two crossings CC: on passing the set of workings HH a portion is taken to supply the men working this coal, which being fresh air direct from above ground enables these places to be worked with candles; and this air having the shortest distance to travel is regulated by the regulator R. The remainder of the air is conveyed up the main road to the pillar working II, and is there thrown upon the working places by the stoppings and doors. ZZ are doors with a "scale" or small supply of air through an opening in them, this supply as shown by the arrows being required to air the passages to the workings; and DD are doors which are required to afford access to the working places.

In Fig. 14, showing the second mode of panel working already described, the process is somewhat different. In this case the only workings are the pillar workings; and here the air is taken to the extremity first, and the pillar working is ventilated much in the same manner as in Fig. 13, the air being directed upon the working places KK by the doors ZZ as before. But it will be observed that there are no regulators in this district of workings; for in this case the air has to travel a greater distance than in Fig. 13, and therefore the regulators are required in Fig. 13, but not in Fig. 14. And it will be observed in Fig. 13 that besides the regulator R there is a regulator X in the middle passage or bord, by which arrangement these two regulators accomplish the triple object of regulating the three currents into the respective sets of workings.

In these two modes of panel working the operations of forming the pillars and working the whole mine are performed at different times and by separate processes. But in the third mode of panel working previously described and shown in Fig. 15, Plate 50, both

operations are performed at the same time. In this diagram the leading places are shown at UU where candles are used; and the dotted portion shows where the pillars are being removed at LL where lamps are used. The removal of the pillars is a very delicate operation, and where much gas exists requires great care. The air as shown by the arrows is first of all taken to the leading places UU where candles are used, and is carried along the most advanced headway EF by the stoppings shown on the diagram. At F it is brought down and passes along the second headway from G to H; it then passes along the third headway from I to K, from which it is taken into the working places LL of the pillar working; a "scale" or small split of air coming through the stopping M is also taken along the fourth headway, at the end of which it joins the current from K. The air is kept upon the working places LL by the doors D and scales Z, as in the previous arrangements; and the regulator R and scale V along the line of the permanent stoppings regulate the quantity of air passing from K into the working places and into the goaf.

With regard to the ventilation in this third mode of panel working it should be observed that the greatest caution is necessary to prevent any sudden fall of stone in the pillar working forcing out inflammable gas and backing it upon the candles. To obviate this it will be seen that two currents are interposed between the air of the goaf and the candles. If any inflammable air were forced out of the goaf it might back upwards to IK and be forced through that line of stoppings; but in that case the current in HIK would prevent its reaching the candles, as they are allowed to be taken only along the headway EF, and there are two lines of stoppings HG and EF to add to the security. It is necessary therefore in order to guard against such a contingency that at least a double current of air and a double line of stoppings should be interposed between the candles and the pillar working: the neglect of this precaution has led to some accidents.

The above general account of the different modes of ventilation will serve to give a general idea of the progress made in the ventilation of the coal mines in Durham and Northumberland within the last half century.

VII. *Lighting mines, safety lamps, &c.*

At the commencement of the last fifty years the only lights used in the coal mines were naked lights, candles or oil lamps, and steel-mills. Figs. 21 and 22, Plate 54, show a steel-mill, which consisted of a cog wheel and pinion A worked by a man or boy, and on the pinion axle a wheel B steeled at the circumference was fixed ; a piece of flint (obtained from the chalk deposits of the south of England) was held in a proper position as at C by the person working the mill, presenting the sharp edge of the flint to the steel wheel B. The effect was that when the wheel was turned rapidly round, corruscations of steel were thrown off as sparks from the wheel in a high state of ignition ; and the illumination produced by these sparks was the light obtained. An expert workman could keep up a continuous succession of sparks, and the light so produced was sufficient to enable a person to perform all the operations of working coal. The frame of the mill is hollowed at the underside, and was held down upon the thigh of the person working it, when sitting to show light to a hewer, the flint being held between the thumb and finger of the left hand grasping the front end of the frame, the handle being turned with the right hand ; when travelling, the back end of the frame was pressed against the chest. With the use of the steel-mill however, two men or one man and a boy were required to perform one man's work ; and the light, though more than sufficient to render darkness visible, was a very indifferent one to work with. The consequence was that the steel-mill was by no means extensively used in working coal, but mostly in exploring the waste and old workings of the mine, and to ascertain where inflammable gas existed : hence large tracts of pillars were left standing which could not be worked to profit by the steel-mill. The steel-mill was considered an almost perfectly safe light to traverse districts impregnated with inflammable gas, even though explosive with a naked light ; when immersed in an atmosphere where the inflammable gas was considerably diluted, the sparks of the mill were reduced to a dull red light ; but where the gas was strong, to a blood red colour ; and this was the test of the presence of inflammable gas. The blood red sparks emitted in the inflammable gas were not generally of a sufficiently high temperature or state of ignition to explode the gas. There were however instances of accidents occurring

from the gas being exploded with the steel-mill; for if the mill were being "played" or plied rapidly in a pure unmixed atmosphere, emitting brilliant corruscations in a high state of ignition, and any of these sparks were thrown into an inflammable mixture of gas, then an explosion might take place. This however was well known by the men, and the mill was never worked fast in such circumstances. Indeed few such cases could ever occur, except in the sudden discharge of gas, or when large quantities of gas in an inflammable state were backed out upon the pure atmospheric air by falls of stone, all of which cases required only care on the part of the person working the mill. The fact that the steel-mill could be used in the presence of imflammable gas without causing explosion accords with the subsequent discoveries of the properties of inflammable gas; namely, that it is ignited by iron or steel only when at a brilliant white heat, and not at a lower temperature.

An extensive explosion about the year 1812 by which 126 men were killed, and another in 1813 by which 62 more were destroyed, drew attention powerfully towards the question whether a safety lamp could be constructed to avoid such accidents. It is said that Humboldt in 1796 contrived a lamp; and in 1813 the late Dr. Clanny also invented a lamp: but both these were isolated lights and therefore not practically useful. It was not until 1815 that a practically useful lamp was invented, and the merit of invention has been divided between the late Sir Humphry Davy and the late Mr. George Stephenson. To both, in the writer's opinion, the credit of an original discovery is due; and from the fact that both were engaged for several months in accomplishing such a desideratum, pursuing entirely different paths, one chemical and physical, and the other mechanical, there is nothing inconsistent in their both arriving at the same result about the same time. Having been present at all the experiments of Mr. Stephenson, and been in constant and daily communication with him in the consideration of his lamp, the writer knows that the path which he pursued was purely mechanical, and that he arrived at the discovery of a safety lamp without any communication whatever with Sir H. Davy or any knowledge that he had made a similar discovery or was advancing towards it; both of them having pursued entirely distinct and independent modes of arriving at the discovery.

Stephenson, finding that explosions of gas in a mine did not communicate between distant points instantaneously but at a definite rate of speed, and that this rate of speed diminished as the area of the passage was diminished, conceived the idea of producing, by the rarefaction of the air in the chimney of a lamp, such a velocity of current upwards through a tube at the bottom of the lamp that when an explosion took place within the lamp the velocity of the air upwards through the tube would be greater than the velocity of the explosion downwards, and hence the explosion would not pass downwards to the exterior air. This led to a dimension of tube being adopted through which the flame would not pass; but as with one hole the lamp was insufficiently supplied with atmospheric air and was thus extinguished, more holes and ultimately perforated tin plates were used; and it was then found that the flame did not pass through such holes. Thus a perfectly safe lamp was discovered.

Sir H. Davy on the other hand, in his researches on flame, finding that red hot iron did not inflame carburetted hydrogen gas, and that it was only at a brilliant white heat that the gas exploded, conceived the idea of interposing surfaces, forming the shield or cover of the lamp, so as to cool down the flame of the gas in the interior of the lamp to such a temperature that it would not explode the gas externally. He accordingly found in the first instance that perforated holes, and ultimately that wire gauze (which presented a greater cooling surface), interposed between the internal and external gas, produced the desired effect; and this formed the discovery of a safety lamp.

It is therefore no disparagement to the memories of these two great men to say that each of them independently of the other discovered a safety lamp. The value of such a discovery is ample for both; for certainly no invention or discovery which has taken place in coal mining has been productive of such important results: the saving of life is of incalculable importance; and the minor result of the invention, namely the recovery of millions of tons of coal which could not otherwise have been worked, is likewise of no inconsiderable importance in a commercial and social point of view.

A great variety of safety lamps have since been constructed, all founded on the same principle, namely that wire gauze of a certain

number of apertures to the square inch, or perforated holes of a certain area, will not allow the flame of carburetted hydrogen gas or inflammable air to pass through them. Sir H. Davy's standard wire gauze is made of wires of ·025 to ·016 inch diameter, having 28 wires or 784 apertures to the square inch, formed into a cylinder of 6 inches height and 1·4 inch diameter. Dr. Clanny subsequently contrived a safety lamp, which is used in some of the collieries in the north of England, the object of which is by the use of glass as a cover to the sides of the lamp to afford more light to the miner.

These three lamps, the *Davy* of Sir H. Davy, the *Geordy* of Mr. Stephenson, and the *Clanny* of Dr. Clanny, are the three lamps now used in the collieries of Northumberland and Durham. These lamps as now in use are shown in Plate 54: Fig. 23 is the Davy lamp; Fig. 24 the Stephenson lamp; and Fig. 25 the Clanny lamp. The Davy lamp is little improved since its original discovery. But the Stephenson lamp is materially improved: the principle of admitting the air to the interior of the lamp and within the glass is retained, the air being however passed through wire gauze after entering through the holes DD; and the glass is covered with wire gauze also, so that in reality it is a Stephenson lamp enclosed within a Davy cover. The Clanny lamp shown is also the most improved form, though the construction is substantially the same as originally made. One objection to the Davy lamp is that, the air being admitted to the interior of the lamp through the wire gauze on all sides, when placed in an inflammable mixture the lamp becomes filled with flame, and the wire gauze is apt to become red hot; and consequently if kept in such an atmosphere too long it becomes dangerous. In the Stephenson lamp however the air is admitted only at the bottom, and not in sufficient quantity to fill the interior when ignited; so that in such a case the lamp goes out, and it is consequently more safe. The great majority of the collieries however use the Davy lamp, which is considered, when well fitted up and when the top is locked to the bottom so that it cannot be removed by the miner, to be a perfectly safe lamp; the miner having instructions to remove the lamp out of the inflammable air when it becomes red hot, experiments having shown that it will not ignite the air until the wire becomes of a white heat.

VIII. *Sinking pits, drainage, &c.*

In the sinking of pits little improvement has been made within the last fifty years: as the working of coal became at greater depths, more powerful machinery was required; but the mode adopted has been generally the same. The strata of the coal measures do not vary much throughout the entire district, being composed of sandstone and shale, with all the varieties of admixture with each other; the sandstones which are pure and gritty containing all the water, while the shales and their varieties are impervious to it. In the district of the Tyne the bed of post called the 70 Fathom post, or a bed of sandstone 120 feet above the High Main coal, contains the most water, and has consequently presented the greatest obstacle to the sinking in that district; as it is however a hard rock, the difficulty consisted entirely in the engine power requisite to pump the water.

It may be remarked here that it was in sinking through this stratum at one of the Killingworth pits that the late Mr. George Stephenson made his first advancement in life. He was then a common brakesman; a Newcomen engine was employed to pump the water, but being overpowered the sinking was stopped; Stephenson having said that he could make the engine pump the water, this led to his employment to do so. The engine was of the common Newcomen construction, condensing by injection in the cylinder, with steam at 3 lbs. per square inch above the atmosphere, having a jackhead cistern placed at an equivalent height above the cylinder for supplying the injection water. Stephenson broke through the rules laid down by Newcomen, increased the pressure of the steam in the boilers to 8 lbs. per square inch, (raising the jackhead cistern a proportionate additional height,) and added an equivalent dead load upon the piston end of the beam, thus obtaining an increase of power of 5 lbs. per square inch on the piston, which cleared the pit of water; and he was then appointed engineer of the colliery.

In the county of Durham the great bulk of the water and the difficulties of sinking occur at the bottom of the magnesian limestone, that rock being extremely porous; and the sand at the bottom containing large quantities of water is sometimes extremely difficult to sink through. A very difficult case occurred in sinking the Murton

colliery. The sand in this pit was reached at the depth of 540 feet from the surface, and the quantity of water raised was 9306 gallons per minute from that depth, which was accomplished by six pumps of 19 inches diameter of barrel and three of 16 inches diameter; the total horse power employed was 1584, and the number of boilers 39. There were three pits sunk through the sand at this colliery, the thickness of the sand being at the East pit 34 feet 6 inches, at the Middle pit 27 feet 8 inches, and at the West pit 26 feet. Such a sinking was probably never accomplished heretofore, considering the thickness of the sand and the immense feeder of water; when sunk through the shafts were tubbed with cast iron in the usual manner.

In the drawing of coals to the surface some changes have taken place. The almost universal mode of drawing the coals to the surface fifty years ago was by baskets or corves made of wicker work from the hazel weedings of the oak woods in the south of England. This has almost as universally been superseded by the coals being put into tubs or square boxes which are placed in what is called a cage, the cage being made to slide up and down the pit by guide rods or timber guides. It had long been the custom to draw the coals to the surface in the midland counties by tubs and cages with guide rods; but it was not until the year 1833 that this mode of drawing coals was adopted in the Newcastle district by Mr. Thomas Y. Hall at the South Hetton colliery: since which time it has been introduced in almost innumerable forms at almost all the collieries in the trade. Figs. 26, 27, and 28, Plate 55, show the general plan of cage now used, which is made of iron framed together, suspended from the winding chain by the rods A, the tub or wagon containing the coals being placed within the cage. Guide rods or conducting timbers B are run down the whole depth of the shaft, against which the cage slides up and down, being kept in its place by the guides C. The cage is generally plated with sheet iron on the two sides, the ends being left open for the tubs to be run in and out at the top and bottom of the pit. Sometimes the cage is of sufficient length to hold two tubs, and sometimes two tubs are also placed above on another platform; and in other cases as many as four tiers of tubs are placed one above another. In some cases instead of timber or

iron guide rods, wire rope is used, which is made fast at the top and bottom of the pit; and in upcast shafts this plan has been found very useful.

The adoption of timber guides has led to the use of a contrivance called a safety cage, to prevent accident from the ropes breaking; the general principle of which is that if the rope should break a serrated projection is thrown out by a spring to lay hold of the timber guides so as to prevent the cage from falling down the pit. Figs. 26, 27, and 28, Plate 55, show the general principle of construction of the safety cages, of which there are a great variety. In this case the two sides of the cage are fitted with levers D, connected with the suspension rods A, one on each side of the guide timbers B; the inner ends of the levers are serrated prongs, which are kept clear from the guide timbers as long as everything is right; but in case of the rope breaking, the levers D are acted upon by springs, causing the prongs to be thrown out against the guide timbers, into which they become jammed, thus preventing the cage from falling down the pit.

Beyond these contrivances and the general improvement of the machinery used in drawing coal and the consequent drawing of much larger quantities at each pit, no further improvements have been made in the drawing of coals.

IX. *Railways and steam colliers.*

Although railways may now be said to belong to the whole world, there is no doubt that they had their origin in the county of Durham; and if we add to this the fact, that the man to whom the world at large is indebted for their development was a Northumbrian, it will be considered that a notice of them is called for in this place, as one of the elements of progress and improvements which belong to the colliery district of Northumberland and Durham.

It would appear that railways were first used in the north of England about the end of the sixteenth or commencement of the seventeenth century, as we have no records of their having been introduced elsewhere before that period. At that time nothing but horses were used, and the railways being of timber the general performance was 42 cwt. drawn on a level by one horse. Malleable

iron plates appear next to have been used, fastened upon the upper surface of the wooden rails to lessen the resistance, and about the year 1738 cast iron appears to have been used for rails; and about 1815 solid malleable iron rails were first introduced for railways.

The size of the carriages or wagons first used on the wooden rails was such as to carry about 2 tons of coals: afterwards when iron rails were adopted, this description of wagon gave way to what is called the chaldron wagon, carrying as a standard weight 53 cwt.; and this description of wagon, until within a comparatively recent period, has been that generally used in the counties of Northumberland and Durham. More recently wagons carrying even as much as 10 tons have been adopted upon the public railways; but upon the private railways 4 tons may be considered as the maximum weight conveyed in one wagon.

In the early period of railways, horses only were used; and though the coals were generally brought from the distant collieries down considerable inclinations, it does not appear that the use of gravity or self-acting planes was resorted to; the full load for one horse was one wagon, whether containing 2 tons or 53 cwt. of coals; and when the acclivity in returning was such that the horse was not able to drag up the empty wagon, a supplementary or "helping up" horse was added. The number of horses employed at that time at some of the collieries may be judged of by the fact that one firm of coal owners, namely Lord Ravensworth and his partners, or as they were then called "The Grand Allies," had 300 hired horses or employed carriagemen in finding that number for the western section of their collieries. It is not ascertained when gravity or self-acting planes were first employed for the motive power on railways; certainly to a very small extent previously to the commencement of the last fifty years. They are now however constantly employed on private lines of railway where the inclination or other circumstances render the line unfitted for the use of locomotive engines.

Fixed steam engines were the next description of motive power in point of time which was used on railways, dragging the wagons by means of ropes from one station to another or up steep planes; they

were exclusively used on private railways. An attempt was made to introduce them upon the Liverpool and Manchester public line of railway; and the propriety of doing so was referred to Mr. James Walker and Mr. Rastrick, who reported against the use of fixed engines, and the result of the trials of the locomotive engines at Rainhill determined the company in the use of locomotive engines. Fixed engines are however extensively used on the short private lines upon steep planes; and in the conveyance of coals underground, which will be described more in detail hereafter.

The use of locomotive engines is of a comparatively recent date. Although as early as 1769 the attention of Mr. Watt appears to have been drawn to this object, and in 1784 he describes modes of applying engines to the moving of wheel carriages, Messrs. Trevethick and Vivian were the first to apply the power of steam to a machine to run upon railroads; and in 1804 a machine was tried by them on the Merthyr Tydvil Railway, which drew after it 10 tons of bar iron a distance of 9 miles at the rate of 5 miles an hour. The obstacle at that time was the supposed want of adhesion of the wheels upon the rails to propel the engine forwards and to drag the load; and to obviate this Mr. Blenkinsop of Leeds introduced in 1811 a rack or toothed rail, into which cogwheels placed on the engine worked, and it was thus propelled forwards. In 1812 Messrs. Chapman had a chain stretched along the line of railway, which the engine laid hold of and thus dragged itself forwards; and Mr. Brunton in 1813 had an engine made with legs by which it was propelled. Mr. Trevethick sent an engine to the Wylam colliery in Northumberland to Mr. Blackett, where it was tried but did not answer. Mr. Hedley however, Mr. Blackett's engineer, improved the engine and applied it by means of the adhesion of its wheels on this railway; and he was unquestionably the first to establish that it was practicable to apply to a certain extent an engine which could propel itself and also drag a considerable load after it by means of the adhesion of the wheels upon the railway.

Mr. George Stephenson then made his appearance in connexion with the locomotive engine. He had been recently appointed engineer to the Killingworth colliery, and as such recommended the use of a

locomotive engine. Mr. Blackett's railway was a tram railway with plate rails, whereas the Killingworth rails were round-topped rails; but experiments were made upon them which proved that the latter rails presented as much adhesion to the wheels as the plate rails, and the resistance to the carriages being less there appeared no reason why a locomotive engine should not be used upon the edge rail as upon the plate rail. Accordingly an engine was constructed by Mr. Stephenson and tried on the Killingworth railway in July 1814; the result was perfectly satisfactory. This engine had two cylinders which were placed vertically on the top of the boiler with a crosshead to each cylinder and two side rods working cranks on the driving wheels. On an ascending inclination of 1 in 330 it dragged a load of 40 tons at the rate of 6 miles an hour, or a gross load of 70 tons; the weight of the carriages being 20 tons, and the engine and tender 10 tons. Upon the Stockton and Darlington Railway with a more powerful engine the gross load conveyed was about 87 tons, the useful load 48 tons, the weight of the carriages being 24 tons, and the engine and tender 15 tons. Such was the performance of the engines improved by Mr. Stephenson until the year 1829, when the important competitive trial took place upon the Liverpool and Manchester Railway; the essential drawback to their utility and performance having hitherto been the want of sufficient evaporating power of the boilers, and the consequent inability to employ engines with larger cylinders or of greater power. The immediate result of this trial of skill was the adoption of multitubular boilers, which presented a vast increase of evaporating surface, and led to the great increase of power of those engines and their consequently increased performance. So that instead of 40 tons of goods conveyed at the rate of 6 miles per hour being the maximum performance of locomotive engines, as was the case within thirty years ago, engines on railroads of the same description are now conveying a nett load of 300 tons of coals from near Newcastle to London over all the intervening gradients at the rate of a minimum speed of 15 miles per hour; and a train of passengers and carriages of more than 150 tons gross weight at upwards of 40 miles per hour: the weight and cost of the engines are however greatly increased.

Most important consequences to the coal trade of the two northern counties have resulted from this development of the locomotive engine. The application of railways and locomotive engines even up to the year 1829 was confined to the conveyance of coals from the collieries to the ships on the rivers Tyne and Wear; and the conveyance of the coals to the various markets of London and the coasting ports was by sailing vessels exclusively. At the present time the conveyance to London and the various seaports is no longer confined to sailing vessels, but we have the railways conveying coals from those counties to the amount of 2,903,497 tons in 1857. This is not however the only consequence resulting from the improvement of railways to the coal trade of Newcastle. In 1857 there was conveyed to within the limits of London from the collieries in the midland district the enormous quantity of 1,206,775 tons of coal, exclusive of the quantity of coals conveyed to the different towns and villages of all the southern parts of the kingdom, which were supplied previous to 1829 by north country coal; the above quantity supplied to London from the midland collieries in 1857 being equal to nearly the entire consumption of London fifty years ago.

The effect of this reduced cost of conveyance afforded by the railway system for coals from the midland district to the metropolis would have been a serious reduction of supply from the northern coalfield, had it not been for an extensive application of steam navigation, by the adoption of the screw in steam vessels, and the employment of iron vessels to carry coals, forming the class of screw colliers as at present used, which have had an important bearing upon the economy of transit of coals "sea-borne." This has all taken place within the last four or five years. The general size of the screw colliers is about 465 tons register and 140 tons engine room, drawing about 13½ feet of water when loaded, being 167 feet in length, 27 feet in width, and 16 feet depth of hold. The engines are generally about 70 horse power, and the vessels carry about 600 tons of coals. Their speed is about 9 miles an hour, and they generally perform the single voyage between London and the northern ports in about 30 hours. They are constructed to use water as ballast in the return voyage, which is a great advantage

and is peculiar to iron vessels, which have a much greater capacity than wooden vessels with the same displacement of water. The iron vessels in fact admit of space sufficient for a cargo of coals which will put the vessel deep enough in the water when fully loaded; and also allow adequate space for tanks to contain about 220 tons of water as ballast in the return voyage. The increased facilities afforded for loading the colliers at the large coal drops enable them to take in their whole cargo of 600 tons often in a single tide; and the result of the employment of these vessels to convey coals to London and some of the southern ports has been that, when proper facilities are given for unloading the coals in about the same time, they make nearly a voyage every week, and a total of between 40 and 50 voyages a year, between the northern ports and London. They thus compensate most effectually for the effect of the conveyance of coals by railway from the midland counties, by reducing the cost of conveyance considerably below that by railway at the lowest rate of $\frac{1}{2}d.$ per ton per mile. The sailing vessels previously employed as colliers made only one fourth the number of voyages per year, averaging about 10 voyages per year, and seldom reaching 12 voyages.

Steam boats themselves may be considered to be included among the inventions of the last half century; for although the project was no doubt started by Symington in 1789, it was not until 1802 that he actually constructed a boat propelled by steam on the Forth and Clyde Canal, for the purpose of towing other vessels; and it was only in 1807 that a steam boat was started on the Hudson River in America by Fulton: the writer recollects going down the Tyne in 1814 with Mr. George Stephenson in the first steam boat on that river. It appears they were first regularly employed on the Clyde in 1812, on the Thames in 1815; and in 1819 the first steam boat crossed the Atlantic, commencing the important era of ocean steam navigation.

X. *Underground conveyance of Coal.*

Consequent upon the improvements of the steam engine, of railways, and of the transit of coals generally, has been the application of those improvements to the conveyance of coals underground, so far as the peculiarity of underground railways admitted. At the

commencement of the present century steam engines had been very little used underground, and their use was almost if not entirely confined to pumping water. The extended use of the steam engine above ground and also that of gravity or self-acting planes has however led gradually to their employment underground.

The thickness of the beds of coal, which never exceed 5 or 6 feet in height, limits to a great extent the application of mechanical power in the conveyance of coals underground; and when that height is reduced to 3 or 4 feet, so that the carriages to be used are obliged to be constructed at or about that height, with wheels about 12 inches in diameter, the economical application of mechanical power is rendered still more difficult. Locomotive engines have thus been excluded from the list of mechanical means, requiring more height than can be practically obtained. Ponies, horses, gravity, and fixed engines with ropes, are therefore employed, according as one or other of them may be most suitable for the circumstances of the situation. Ponies are exclusively employed in the working places, to drag the coals to the main road; and the latter being made of a greater height, horses or the other mechanical modes are then employed.

Fig. 20, Plate 53, is a diagram showing the several applications of motive power, and is intended to represent a coalfield lying at a general inclination of 1 in 12, with the various modes by which the coals can be most economically conveyed from all the different parts to the pit P, up which they are to be drawn to the surface. The black lines show the several roads: the dotted lines G and T represent the water levels for draining the mine, which are driven at an inclination of 1 in 200; that being about the inclination at which water will find its way along the levels of a coal mine. Generally the horse road is laid down along the water levels; but if it is desired to adopt that inclination which will make the amount of traction equal in both directions, the loaded carriages being dragged towards the pit P and the empty ones from it, the road must be made at an inclination of about 1 in 130 down towards the pit, supposing the friction of the carriages is equal to $\frac{1}{80}$th part of their weight. This was found to be the friction of the underground carriages in the experiments made by the writer, the diameter of the wheels being from 12 to 15 inches

and the axles ·69 inch diameter; if the wheels are 2 feet in diameter the friction is reduced to about $\frac{1}{100}$th part of the weight, but it is only in some collieries that wheels can be used of 2 feet in diameter. The carriages contain 9 cwt. of coals each, the empty carriage weighing about 3 cwt. Where horses are obliged to be employed it is therefore advisable that the road should be laid at an inclination of about 1 in 130 down towards the pit, as shown at HH on the plan, Fig. 20.

The least expensive mode of conveying coals underground is the employment of gravity; it is therefore desirable that this power should be made available wherever practicable. The results of the writer's experiments on underground carriages and railways show that self-acting inclined planes or gravity can be used with advantage where an inclination of 1 in 30 can be obtained. Suppose therefore the ideal coalfield A B C D to lie at a slope of 1 in 12, or to rise 1 inch per foot in the direction A B and D C, dipping as much of course in the opposite direction, the dead level being at right angles to this direction, or along the lines A D and E F. Then the draining water levels GG would be driven in the direction shown on the diagram, in order to give an inclination of 1 in 200; the horse roads HH would be driven at 1 in 130, which would make the resistance the same in both directions with the loaded carriages going downhill towards P and the empty carriages uphill from P. The inclination at which gravity will act having been ascertained by experience to be 1 in 30, the coals above the lines I I would be conveyed by self-acting planes; and as from their direction the lines K and L would rise 1 in 12, self-acting planes might be used on those lines likewise, and the coals could be brought out by gravity to the pit P. It will be seen therefore that with a bed of coal lying at a slope of 1 in 12 all the coals on the rise or upper division of the coalfield, forming the area E B C F, may be brought out or conveyed to the pit P by gravity, except along any horse roads which may be required in the water level direction to convey the coals to the top of the self-acting planes or from the bottom of them to the pit.

Next with regard to the coal below the level of the pit P, in the area A E F D, which has all to be conveyed up the inclined bed of coal to the pit. These coals are now supposed to be conveyed by fixed steam engines dragging the carriages by means of ropes; the engines

being generally placed at or near the bottom of the upcast shaft to get rid of the smoke of the boilers. The most simple case is where the descending inclination of the plane is such that the empty carriages have sufficient force to drag out the rope after them; the rope being subsequently used by the engine to drag the loaded carriages up the plane. It is therefore of great consequence to determine the rate of inclination on which the empty carriages can drag out the rope; and a great number of experiments have been made by the writer for this purpose, which resulted in the conclusion that with the description of carriages already stated the empty carriages have sufficient force to drag the rope after them at an inclination of 1 in 28. Hence all the coal above the lines MM on the plan can be conveyed by the engine to the pit P, being conveyed by self-acting planes down the lines NN to the engine planes MM. In like manner the planes O R R being all of greater inclination than MM can be worked by engines in the same way. There are also cases in practice where the rope from the engine works along the plane M as far as the branch R and then turns down the branch R. By this method therefore fixed engines placed at the bottom of the shaft may be made available to drag to the pit P all the coal within the area S S P, and also from the points UU of the lower horse road, when the coal lies at a slope of 1 in 12 as hitherto supposed.

But suppose the coal lies in a more horizontal position, or it be required to employ engine power on the horse roads or in other parts of the underground workings where the roads do not descend at a slope of 1 in 28, and where the inclination therefore is not such as that the empty carriages will drag out the rope after them. In this case an endless rope is employed winding round a sheave at the bottom of the engine plane; or two ropes wound on separate rolls and a tail rope attached to the end of each of the ascending and descending trains and winding round a sheave as before. By this means planes of any inclination less than 1 in 28 can be traversed, and to any moderate distance, say $1\frac{1}{2}$ miles from the shaft.

By one or other of these methods therefore coals may be conveyed underground from any point within a coalfield of 9 square miles, or from any point $1\frac{1}{2}$ miles from the pit in every direction. The application of these modes of underground conveyance has reduced the cost of

conveying coals underground to a considerable extent; and in some of the collieries the coals underground are almost entirely conveyed by engine power.

Placing the boilers of the engines underground is attended with great risk of setting the coal on fire; it has therefore been a subject of enquiry how far the working power of the engines is affected by placing the engine on the surface, and having the ropes to lead down the shaft; or in some cases by placing the machinery of the engines underground and the boilers on the surface, and conveying the steam by pipes down the pit; and also in some instances conveying the waste steam up the pit again. All these different plans are employed, and it has been found that the steam can be conveyed down pits of 900 feet in depth without any perceptible difference between the pressure of the steam in the boilers on the surface and in a reservoir of steam near the cylinders underground, the diameter of the pipes being 10 or 11 inches for an 80 horse power engine. An extensive series of experiments are given in the Transactions of the North of England Institute of Mining Engineers, which were made at several collieries by the writer, and are very important in their results with regard to the economy of the use of steam when the engines are placed at considerable distances from the boilers.

TABLE I.

Section of Strata at the Seaham and Seaton Pits.

		Feet.	Ins.	Feet.	Ins.
Outset		3	0		
Soil		1	0		
Brown Clay; strong and stony		53	0	57	0
Soft Marl		6	0		
Brown Limestone; strong and marly partings		48	0		
Brown Limestone; strong	Magnesian	120	0		
Limestone; strong with water		84	0		
Limestone; mixed with sand.	Limestone	4	0		
Strong Brown Limestone		82	6		
Sand; with water		10	0	354	6
Grey Metal; mixed with blue		8	4		
Red Metal, or Sandy Post		7	6		
Strong White Post; mixed with whin		2	5		
Grey Metal; with post girdles		3	2		
Dark Metal; with post girdles		4	1		
Grey Metal		34	5	59	11
Coal			3		3
Dark Grey Metal; with thin post girdles		16	11	16	11
Coal			5		
Band			2		
Coal			8		
Band			1		
Coal		1	4		
Band			2		
Coal		1	8	4	6
Grey Metal		2	4		
Grey Post; with whin girdles and metal partings		5	11		
Coal			1		
Dark Grey Metal		4	4	12	8
Coal		1	0	1	0
Grey Metal		9	4	9	4
Coal			3		
Dark Grey Metal		1	1		
Coal			2	1	6
Dark Grey Metal		6	4		
Strong White Post		12	4		
Dark Grey Metal		14	3		
Black Stone; with ironstone girdles		6	0	38	11
Coal		2	8		
Band			4		
Coal		1	11	4	11
Grey Metal		11	3	11	3
Coal			1		1
	Carried forward			572	9

	Feet.	Ins.	Feet.	Ins.
Brought forward			572	9
Grey Metal	7	6		
Grey Post	7	6		
Grey Metal	73	3	88	3
Coal		8		
Black Stone; mixed with coal		3		11
Strong Grey Post; with post girdles	13	7	13	7
Foul Coal		7		7
Grey Metal; with post girdles	15	1		
Strong White Post	25	9		
Grey Metal	33	10		
Strong White Post; with water	43	9		
Dark Grey Metal	34	3	152	8
Coal		3		
Band		7		
Coal		3	1	1
Strong Grey Post; with metal partings	8	3	8	3
Coal		8		8
Grey Metal; with black partings and ironstone balls	16	6		
Strong Grey Post; mixed with whin	33	3		
Grey Metal	4	3	54	0
Coal	2	10	2	10
Strong White Post; with water and metal partings	36	0		
Grey Metal	1	0		
Strong White Post; with water	18	9	55	9
Coal	2	3	2	3
Dark Grey Metal	6	7		
Black Metal; mixed with coal	14	0		
Strong White Post; with metal partings and water	31	4		
Dark Grey Metal	13	1	65	0
Coal		8		8
Grey Metal	13	2	13	2
Coal		6		6
Grey Metal; with post girdles, and water	26	3	26	3
Coal		8		8
Grey Metal; with post girdles	99	0	99	0
Coal. **Five Quarter Seam**	3	5	3	5
Strong Grey Metal Stone; with post girdles	34	0		
Black Metal; mixed with coal	2	0		
Grey Metal	4	5	40	5
Carried forward			1202	8

	Feet. Ins.	Feet. Ins.
Brought forward		1202 8
Coal	1 0	1 0
Grey Metal; with thin girdles	23 0	23 0
Coal	1 2	1 2
Strong Grey Metal Stone	27 5	
White Post	16 5	
Black Post; seamy	1 2	
Strong Grey Post; with metal partings	54 4	99 4
Coal **Main Coal Seam**	6 1	6 1
Strong Grey and White Post	15 1	
Black Stone	2 6	
Grey Metal; with ironstone girdles	28 11	46 6
Coal **Low Main Seam**	3 6	3 6
Grey Metal; with post girdles	79 3	
Black Metal	3 0	82 3
Coal	11	11
Strong Grey Metal; with post girdles	7 10	7 10
Coal	5	5
Grey Metal and post girdles	9 5	9 5
Slaty Coal	1 2	1 2
Strong Post; mixed with grey metal and post girdles	34 7	34 7
Coal **Hutton Seam**	4 10	4 10
Bottom Coal and shale	6 9	
Strong Grey Post; with metal partings	28 10	
Black Metal	1 2	
Grey Metal Stone; with post girdles	7 7	
Black Stone	1 0	45 4
Coal	1	1
Strong White Post	31 7	
Black Metal; mixed with coal	11 2	
Dark Grey Metal; mixed with coal	7 4	
Strong White Post	1 8	
Black Metal	3 0	
Strong White Post	48 7	
Grey Metal; with thin post girdles	13 6	116 10
Coal **Harvey Seam**	2 10	2 10
Grey Metal	6 0	
White Post	4	6 4
Total depth		1696 1

TABLE II.

Section of Strata at Murton Colliery, from the Main to the Hutton Seam.

		Feet.	Ins.	Feet.	Ins.
Coal	**Main Coal Seam**	6	2	6	2
Strong White Thill		2	0		
White Shivery Post		4	7		
Black Stone		1	2		
Grey Metal		8	2		
Strong White Post		4	0		
Grey Metal; mixed with ironstone girdles		4	8	24	7
Coal			3		3
Dark Thill		3	0		
Grey Metal; with ironstone girdles		22	3	25	3
Coal		1	1	1	1
Dark Thill		2	0		
Grey Metal; with ironstone girdles		6	4	8	4
Coal			2		2
Dark Thill		4	0		
Grey Metal; with ironstone balls		12	5		
Grey Metal; with post girdles		21	3		
White Post; with metal partings		10	0		
Strong White Post		24	7		
Strong Grey Metal		5	11	78	2
Coal	**Low Main Seam**	4	7	4	7
Dark Swad			10		
Black Stone			11		
Dark Grey Metal; with post girdles		9	6		
White Post; with partings		21	5		
Dark Post; leafy		5	4		
Black Stone		7	4	45	4
Coal		1	8	1	8
Black Stone		6	0	6	0
Coal			6		6
Black Stone		11	4	11	4
Coal			10		10
Grey Metal		4	0		
Strong Post; mixed with whin		19	0		
Grey Metal; mixed with post girdles		11	9		
Black Stone			7	35	4
Coal	**Hutton Seam**	5	0		
Band		1	0		
Bottom Coal		1	2	7	2
	Total			256	9

TABLE III.

Section of Cleveland Ironstone Formation
at Eston Nab near Redcar,
near commencement of section drawn in Fig. 6, Plate 45.

	Feet.	Ins.	Feet.	Ins.
Soil and other strata unproved (approximate)	50	0		
Freestone (approximate)	60	0		
Shivery Post, patches of jet and fire clay (approximate)	54	0	164	0
Ironstone—Top Seam	Ins.			
Nodular Ironstone	1	1		
Shale	2	4		
Nodular Ironstone	3	3		
Shale	1	5		
Nodular Ironstone	1	1		
Shale		6		
Nodular Ironstone	1	1		
Shale		6		
Ironstone band (varying)	9	9	6	0
Total thickness of Ironstone 1 ft. 3 ins.				
Lias shale, including jet rock at bottom (approximate)	210	0	210	0
Ironstone	Ins.			
Ironstone band	2	2		
Shale	2	5		
Ironstone band	2	2		
Shale . . mixed with nodules of Ironstone, say	2	1 10		
Ironstone band	3	3		
Shale	1	0		
Shale, inclining in some parts to fire clay	4	2	10	0
Total thickness of Ironstone, say 9 ins.				
Ironstone—Main Seam	Feet. Ins.			
Ironstone, Top block (left as roof)	11	11		
Parting (regular at outcrop but not so after)				
Ironstone, Second block (left as roof near outcrop)	2 3	2 3		
Main parting (good at outcrop but lost further in)				
Ironstone, Main block (uniform)	12 0	12 0		
Parting (lost after leaving outcrop)				
Ironstone, Bottom block (varying)	1 10	1 10	17	0
Shale		7 0		
Ironstone band (called 2 ft. band)	1 8	1 8		
Shale		6 0		
Ironstone band	10	10	15	6
Total thickness of Ironstone 19 ft. 6 ins.				
Blue shale (approximate)	36	0		
Various beds, grey post and metal, stone, &c. (approximate)	93	6	129	6
		Total depth	552	0

TABLE IV.

Section of Cleveland Ironstone Formation
near Staithes,
at southern extremity of section drawn in Fig. 6, Plate 45;
about 16 miles south-east of section in Table III.

This section passes through the Main seam of Ironstone only, the Top seam being here removed by denudation, as shown in the section drawn in Fig. 6.

	Feet. Ins.	Feet. Ins.	Feet. Ins.
Soil		4 0	
Reddish Clay		10 0	
Alum Rock		7 0	
Jet Rock		11 0	
Blue Shale		61 0	
Ironstone Dogger	6	6	
Blue Shale		3 6	97 0
Ironstone—Main Seam			
Ironstone	3 0	3 0	
Blue Shale		7	
Ironstone with blue shale partings	2 10	2 10	6 5
Blue Shale		1 0	
Ironstone	3	3	
Blue Shale		3	
Ironstone	4	4	
Blue Shale		1 6	
Ironstone	5	5	
Blue Shale		5	
Ironstone	4	4	
Blue Shale		3	
Ironstone	6	6	
Blue Shale		5	
Ironstone	7	7	
Blue Shale		4	
Ironstone	4	4	
Blue Shale		4	
Ironstone	5	5	
Blue Shale		3 0	
Ironstone	1 6	1 6	12 2
Blue Shale		9 9	
Ironstone	10	10	
Blue Shale		15 0	
Ironstone	2 0	2 0	
Blue Shale (down to sea level)		33 0	60 7

Total thickness of Ironstone 13 ft. 10 ins.

Total depth 176 2

TABLE V.

Section of Cleveland Ironstone Formation in Rosedale Cliff at Rosedale Docks, on the coast about 2 miles south-east of section in Table IV.

	Feet.	Ins.	Feet.	Ins.
Soil	3	0		
Clay	14	0		
Freestone	26	0		
Fire Clay	4	6		
Freestone Shale	5	5		
Blue Shale		10	53	9
Ironstone—Top Seam	Feet.	Ins.		
Ironstone Dogger	3		3	
Blue Shale			2	2
Ironstone, Top block, very good	1	6	1	6
Parting				
Ironstone, Bottom block	2	10	2	10
			6	9
Total thickness of Ironstone 4 ft. 7 ins.				
Cement Dogger			10	4
Alum Shale or Rock			160	0
Jet Dogger			1	0
Jet Rock			19	0
Blue Shale, exposed on the sea beach			12	0
Lias Shale			59	5
			261	9
Ironstone—Main Seam				
Ironstone. Top block (working part)	2	9	2	9
Shale (working part)				8
Ironstone, Bottom block (working part)	3	1	3	1
Shale				3
Ironstone		3		3
Shale				4
Ironstone		6		6
Shale				5
Ironstone		6		6
Shale				4
Ironstone		6		6
Shale				5
Ironstone		7		7
Shale				4
Ironstone		5		5
			11	4
Total thickness of Ironstone 8 ft. 7 ins.				
Total depth			333	7

TABLE VI.

Section of Cleveland Ironstone Formation
in Vale of Esk near Whitby,
extreme southernmost part of district,
about 12 *miles south-east of section in Table* V.

	Feet. Ins.	Feet. Ins.	Feet. Ins.
Sandstone		25 0	25 0
Ironstone—Top Seam			
Ironstone	12 0	12 0	12 0
Total thickness of Ironstone	12 ft. 0 ins.		
Lias Shale		92 0	
Various strata not identified		51 0	
Lias Shale		55 0	
Ironstone			
Laminated Ironstone band	6 0	6 0	
Shale		8 4	
Ironstone band	1 2	1 2	
Shale		3 6	
Ironstone	6	6	
Shale		4 8	
Ironstone	6	6	
Shale		4 4	227 0
Total thickness of Ironstone	8 ft. 2 ins.		
Ironstone—Main Seam			
Ironstone	4 0	4 0	
Shale (*Pecten* band)		10	
Ironstone (*Pecten* band)	1 0	1 0	
Shale		17 4	
Ironstone	3 8	3 8	
Shale (*Avicula* band)		10	
Ironstone (*Avicula* band)	2 0	2 0	29 8
Total thickness of Ironstone	10 ft. 8 ins.		
Shale		35 1	
Ironstone	7 3	7 3	
Shale		30 0	
Shale with nodules and thin bands of Ironstone	9 2	22 9	95 1
Total thickness of Ironstone	16 ft. 5 ins.		
		Total depth	388 9

Explanation of Terms used in the Tables.

Post—silicious sandstone
Grey Post—grey gritty sandstone
Dark Grey Post—dark ditto
Strong Grey Post—strong ditto
Shivery Post—laminated ditto
White Shivery Post—white laminated ditto
White Post—pure silicious sandstone
Strong White Post—hard ditto
Metal—shale, partly silicious and partly bituminous
Black Metal—bituminous black shale
Blue Metal—argillacious blue shale
Grey Metal—silicious grey shale
Dark Grey Metal—silicious bituminous shale
Red Metal or Sandy Post—red sandstone
Thill—underclay, fireclay, argillacious shale
Black Stone—argillacious shale, or clay
Dark Swad—ditto
Girdles—thin beds of sandstone or hard shale

Mr. N. Wood exhibited a series of specimens of safety lamps, from the earliest attempts including the original steel-mill, down to the most recent improvements.

Mr. T. S. Prideaux remarked in reference to the comparative question of machine ventilation and furnace ventilation that he remembered seeing Brunton's fan at work, which was tried many years ago for ventilating a colliery, and had come to the conclusion that the quantity of coal used in the ordinary ventilating furnaces was considerably greater than would be required for ventilation by means of a fan, if properly proportioned so as not to waste power by giving too great velocity to the air.

Mr. N. Wood had made trial of two fans at the Lundhill colliery, which gave a total discharge of about 20,000 cubic feet of air per minute; and they certainly worked well, and were very serviceable for that special application, where it was necessary to resort to some

temporary means of ventilation from the top until the pit was cleared; but the case was a very different one when such enormous quantities of air had to be dealt with as the 250,000 cubic feet per minute constantly drawn from one shaft at Hetton colliery; and he did not see the practicability of any mechanical ventilation exceeding that performance.

Mr. M. Dunn remarked that, in reference to the invention of the safety lamp, Dr. Clanny of Sunderland had the credit of being really the first inventor of a safety lamp, as he remembered his lamp being brought out in 1812 and 1813, and those of George Stephenson and Sir Humphry Davy were not until 1815. The system of panel working in coal pits he remembered being introduced first by Mr. Buddle in 1815, for the purpose of limiting the spread of explosion and of creeps, and it was a great invention at that time. Mr. Buddle also invented the plan of splitting the current of air for ventilation of a pit, which was first applied by him at Hebburn colliery, where all the air in one continuous current had previously a course of 40 miles to traverse; and a great improvement was effected by splitting this current into several distinct courses of shorter length; the effect of splitting being not only to give fresher air but also an increase of the aggregate quantity. A hot cylinder arrangement was also tried by Mr. Buddle as a modification of the furnace ventilation, in which the air travelled through a heated cylinder in the centre of a furnace upon the surface.

Mr. W. Fairbairn considered they were much indebted to Mr. Wood for the valuable description of the colliery working that had been given in the paper, which would form an important and valuable record in the proceedings of the Institution. It was a singular circumstance that had been mentioned in the paper, that three of the different varieties of coal all occurred in the same bed; and they had had an opportunity of seeing at Elswick on the previous afternoon a large block of coal which contained two of the varieties described closely united to each other. Great improvements had certainly been made in the coal mining of that district since the time that he remembered being at Percy Main colliery in his youth; there had also been a great improvement in Lancashire, and they had now in operation at Dukinfield one of the deepest shafts at present worked, 2040 feet

depth, which was now being worked in one lift by a large winding engine of 400 horse power that he had erected for the purpose. At this shaft he was now engaged together with Mr. Hopkins of Cambridge in trying some interesting experiments upon the rate of increase of temperature as the depth increased, and the results at present obtained gave a rise of about 1° Fahr. for each 50 feet in depth.

As to the mode of ventilation he felt satisfied that so large a quantity of air as a current of 250,000 cubic feet per minute could not be accomplished by mechanical means whether of a fan or a pump, and that the only resource was the furnace ventilation where those very large quantities had to be supplied. It might be noticed that in the case of large blast furnaces only about 10,000 cubic feet per minute were supplied by an engine of 160 horse power at the pressure required by the furnaces. The statistics given in the paper were very interesting, respecting the extraordinary increase that had taken place in the quantity of coal raised, from 3 to 16 million tons per year; and with this great increase still progressing, he would like to ask what idea was entertained about the probability of working out the whole of the coal.

Mr. T. S. Prideaux observed that in the case of the air supplied to blast furnaces it was compressed to about 3 lbs. per square inch, and the large power of the engine was mainly required for that compression; but in the case of mine ventilation the power required would be only that necessary to overcome the friction of the air through the passages of the mine.

Mr. N. Wood replied, in reference to the question of the probable time of working out the coal, it had to be remembered that the number of seams of coal worked was continually increasing, and another seam was discovered and brought into operation when one became exhausted, so that they kept increasing the field for supply. It was consequently very difficult to form any calculation on the subject, but a term of 3000 years had been named, and another estimate had been 1500 years; the great increase that was continually going on in the sources of supply made the latter estimate a pretty safe one, and before that time had expired some other source of motive power might perhaps be discovered; lower coals would be brought in after the upper coals were exhausted, by sinking deeper with the improved means of winding and

pumping that were now available. There was a very deep colliery at Sunderland, the Monkwearmouth colliery, 1710 feet deep, which was one of the deepest in the country, and might be visited by the members on the following day; a 150 horse power winding engine was employed at the pit with all the most modern appliances.

In regard to the origin of the safety lamp, Dr. Clanny's lamp had certainly the priority of invention, but from its imperfection of principle he could never feel satisfied that it was a very safe lamp; and he thought that those of Davy and Stephenson alone could be looked upon as truly the origin of the safety lamp.

The CHAIRMAN observed they were very much indebted to Mr. Wood for the valuable and interesting paper he had given them; it was of particular interest and value to have the personal description and explanation of one who, like Mr. Wood, was individually connected with the discoveries and improvements that had been made, and who was so intimately acquainted with the district, and so long personally associated with the late Mr. George Stephenson.

He proposed a vote of thanks to Mr. Wood for his paper, which was passed.

The following Paper, by Mr. John Anderson, of Woolwich, was then read :—

ON SOME APPLICATIONS OF THE COPYING OR TRANSFER PRINCIPLE IN THE PRODUCTION ON WOODEN ARTICLES.

A distinguishing characteristic of the arts and manufactures of the present century as compared with those of the past consists in the application of the principle of machine copying, in contradistinction to dependence on the skill of the operative, in the production both of the ordinary articles of commerce and of the munitions of war. Engineers are so familiar with this principle in their every day pursuits, that it frequently escapes their notice; yet a closer inspection will show that almost all machines that are intended to change the form of materials are constructed on some modification of this principle, of having the form in some way or other contained in the apparatus, with the specific object of imparting that form to the materials under operation; and it will generally be found that every process which is done well, and which at the same time is done cheaply, is performed by some skilfully arranged development of this principle. The advantage of keeping first principles steadily in view in practical applications of science is generally conceded: the knowledge of facts is considered good; but to know the law of the facts is considered better, and much more likely to hasten onwards their more extended application. A complete exposition of the various applications of this copying principle in the several arts and manufactures of the world would form a highly interesting and valuable volume.

Within the last few years a remarkable change has taken place in this respect. With regard to the tools of the smithery, production by the hammer and hand of the smith is fast giving place to production by means of apparatus constructed upon the copying or transfer principle: such as dies under the American drop hammer, the steam hammer, and the forging machine; the employment of rolls containing on their surfaces the pattern of what is wanted; and the use of oscillating dies imparting the form to the red hot mass upon a moving table. In each case it is seen that the general tendency is to obtain

the form and dimensions of the article produced by the transfer of both from an apparatus prepared with care; and to dispense with that care in the future actual production. The moulding operations of the foundry are pre-eminently copying; or, if it is attempted to analyse the recent improvements in the moulding of wheels, shells, railway chairs, and such articles, it will be found that all are designed with a view to have the accuracy and perfection of form provided in the apparatus, from which it is then transferred to the sand without so much skill being required on the part of the workman who performs the ramming of the mould. The other workshops of the engineer present that invaluable development of the copying principle termed the slide rest, assuming every variety and modification in the several machines used for turning, boring, drilling, planing, or shaping. The same principle in combination with circular cutters affords the machinery of the Small Arm Factory, the endless variety of which would alone form an interesting subject.

The object of the present paper is to give a description of a few applications of the copying principle in the production of certain articles mostly in connexion with the simple operations of wood-turning, which have been more immediately brought under the notice of the writer; and although they are trifles in themselves, still it is only by each one making a small contribution from time to time that the improvements in the details of the several workshops can be made generally known to one another.

During a short professional tour in the United States in 1854, the writer was much struck with the many simple and ingenious contrivances there introduced, in order to apply the copying principle in connexion with ordinary hand-lathe operations, where generally in this country more would be dependent upon the skill or attention of the turner or upon special machinery. For example, in the production of articles where there is repetition and which are to be turned in a common lathe, the application of certain very simple additions tends greatly to facilitate the operation and to enable the operator to dispense with the usual measuring and gauging and the use of callipers, which generally occupies so much time.

A simple arrangement of a copying lathe is shown in Fig. 1, Plate 56. At the front of the lathe and parallel with the piece of wood A to be operated upon, there is fixed a straight edge B made of hard wood, with the upper or straight edge slightly hollowed. At the back of the lathe there is a similar fixture C, only the upper edge is not straight but resembles the irregular form of the required article. The gouge or turning instrument D, instead of being held in the hand of the turner over a rest, is fixed into a piece of wood E, the arrangement slightly resembling that of a carpenter's plane, having one end adapted to slide firmly on the straight edge B at the front of the lathe, while the other is adapted to trace the irregular line C running along the back. In order that the workman may gradually reduce the wood to the proper diameter without the risk of digging into the mass and thereby breaking the cutting instrument, a small wedge of wood F is attached by a loop to the little finger of his right hand, and at the commencement of the operation is inserted between the toolholder E and the irregular pattern C at the back of the lathe, but is gradually withdrawn as the article approaches the required diameter; and at the last a finishing tool is slowly and carefully drawn along the two guides B and C, thus producing the exact pattern without any effort, and in much less than half the time in which it could be done in the common way.

On a similar plan to the foregoing but differently arranged is the American system of turning long poles of small diameter, as shown in Fig. 2, Plate 56. The wood G to be turned is first cut by a circular saw into square rods of the required length; these are then placed between the centres of a turning lathe, with the corners still upon them. The toolholder or cutting apparatus H slides steadily upon two parallel straight edges I I placed respectively at the front and back of the lathe: this toolholder consists of a metal socket H having cutting gouges K and L at each end; the foremost gouge K is set to reduce the square rod to the internal diameter of the socket H, in order to obtain perfect steadiness; while the second or finishing gouge L is set to reduce the pole to the required diameter. To relieve the workman from the trouble of pushing the socket H with its cutting tools along the lathe, the interior of the socket is made with

a screwed surface; and the first gouge K being set to give a tight fit, the thread which is thus formed upon the wood draws the socket along; and as the second gouge L is close to the hinder end of the socket, the thread does not make its appearance, being cut off by the second gouge, which is set to give the proper finished diameter to the work. In turning long small poles of an irregular figure, the second tool L is not a fixture upon the socket, but is held in a toolholder having one end hinged upon the socket while the other traces the required pattern placed alongside, thus causing the tool to rise or fall as it slides along the pattern.

It may be mentioned that the American wood turners use a centre which is not common in this country; and having been introduced into the Royal Arsenal with great advantage, its general application can be recommended. This lathe centre, which is shown in Fig. 3, Plate 56, instead of having the ordinary sharp point, is formed at the extremity with a hollow cup M, surrounded by a sharp circular edge; this when pressed into the revolving wood forms a hard centre within itself, by compression of the wood within the conical cup, which is better adapted both to retain the oil and also to continue uninjured during a long period.

The method of turning the Sabots of blocks of wood which are attached to round shell, as performed in the arsenal at Woolwich, affords another illustration of the successful application of the copying principle. Hitherto these articles have been produced by the wood turner with the gouge, chisel, and gauges, in the usual manner; it was a monotonous and very laborious process, and a skilled workman could produce only about fifty of them per day.

By the new method, the wood is first cut out of the plank into circular pieces by means of an ordinary trepanning tool, costing for wages an average of 7*d.* per hundred. The wooden disc is then perforated by a drilling machine, in order to prepare it for being screwed upon the face plate of a turning lathe.

The first turning process is to form the exterior surfaces; and for that purpose the wood is screwed upon the centre screw of the face plate, as shown at A, Fig. 6, Plate 57. The tools or gouges B and C

that are required to produce the form are contained on separate sliding rests D and E combined together upon one saddle F, both being actuated by the movement of a single handle G. The saddle F itself is made to slide upon the lathe bed in the ordinary manner, by means of a rack and pinion, and is moved by the left hand of the workman by means of the handle H. The dimensions of the sabot are determined by a stop upon the lathe bed against which the saddle F is pressed, and also by the adjustment of the gouges.

The next and last operation is to hollow the sabot for the reception of the shell. For this purpose a similar lathe is employed, shown in Fig. 7, Plate 58; the block A is held in a universal chuck adapted to the article. The required hollow being part of a true circle, the gouge B is fixed upon a holder which is capable of turning on its axis by means of a handle C; the radius of the circle described by the gouge depending on the distance at which its cutting edge is set from its centre of motion. The toolholder is mounted upon the saddle D of a lathe, as in the former operation, the depth to which the hollow is cut being determined by a stop fixed upon the lathe bed and adjusted with reference to the face plate. In performing the operation the workman moves the saddle D with his left hand by a rack and pinion by means of the handle E, while with the other hand he gently moves the handle C of the toolholder, making the gouge describe an arc of a circle.

It will thus be seen that no skill is required during any of the producing operations, and that the form and dimensions of the article are in each case contained in the apparatus. To make sabots of other forms, the several slide rests are readjusted upon the saddle. The saving in wages effected by these arrangements amounts to more than four fifths of the original cost.

For another but smaller class of articles of similar shape, of which three or four hundred thousand are required daily, a different modification of the principle of copying is employed. The conical plug of the Minié bullet is made of box wood by self-acting machinery. In this manufacture the conical form of the plug is contained in a revolving cutter which is fixed in a lathe spindle and driven at a high velocity.

The wood having been first cut up into long square rods by means of circular saws, one of the wooden rods is fixed upon the lathe saddle and pushed forward against the cutter; this gives a conical form to the end of the rod, which is then cut off by means of a circular saw, forming a plug of the required shape and dimensions.

The machinery for effecting this object is variously arranged; one of the best combinations is shown in Fig. 9, Plate 59. The headstock containing the cutter A, shown full size in Fig. 10, in addition to the revolving motion of the spindle has a longitudinal movement imparted to it by means of the grooved cam B and the lever C; the wooden rod to be cut D being held firmly by the saddle E, the headstock and cutter are gently pushed against its extremity, thus forming the conical end to the rod, and are then withdrawn again.

The second operation is to cut off the plug. To accomplish this the bed and saddle E carrying the wooden rod D are placed upon the top of a rocking frame, which also is moved by a cam F and connecting rod G but in a direction at right angles to the sliding motion of the headstock. When the conical end has been formed and the headstock drawn back, the woodholder E is pushed transversely against the circular saw H, and the finished plug drops into a box I; after which the saddle E is brought back into line with the headstock, and an intermittent self-acting feed motion K pushes the rod of wood forward into the position for forming another plug.

In some of the earlier machines the saw made a transverse movement to cut off the plug; by that arrangement the plugs and the chips were mixed together in the same heap, and the labour for their separation cost more than for the manufacture; but by the new arrangement, the plugs and the chips are kept separate and the cost in wages is thereby reduced more than one half.

A modification of the copying principle employed in a machine for forming square holes or mortices in wood is another example.

It consists of a combination of a square box-chisel with a screw auger working within it, shown in Figs. 4 and 5, Plate 56. The chisel N forms a square socket of the same external dimensions as the required mortice, having its four cutting sides chamfered inwards.

Within this chisel and combined with it there is a revolving screw auger O having an independent circular motion, its cutting edge being flush with that of the chisel. The action of the machine consists in forcing the square chisel against the wood with a pressure sufficient to make an incision, and the auger drills out about $\frac{7}{8}$ths of the required hole, the chisel making the round hole square, and with its bevilled edges pushing the chips against the running auger, by means of which they are withdrawn.

The Blanchard turning lathe contains a modification of the copying principle, susceptible of endless application in the production of irregular forms; it is used in turning gun stocks, spokes of wheels, shoe lasts, busts, and similar articles.

It may be described as two lathes placed side by side and parallel with each other, as shown in Fig. 8, Plate 58; the one lathe containing the pattern F, the other the lump of material G out of which the article is to be formed, and both lathes having the same motion. The sliding rest which holds the turning tool H also carries a dumb instrument I for tracing the pattern F, and by means of a weight or spring this tracer is kept in contact with the pattern. As usually constructed the turning tool H consists of a revolving wheel, having its periphery fitted with cutters, and driven by an independent strap at about 2000 revolutions per minute. The tracer I is also of the same external circular shape and size as the tool, and is capable of turning freely on its axis. The action of the machine consists in imparting to the cutter H the motion of the tracer I, as produced by the irregular surface of the pattern F; the tracer being in contact with the pattern, as the latter turns round the tracer moves out and in accordingly; and as the material G in the second lathe has the same motion as the pattern, and the cutter has the same outside form as the tracer, it necessarily produces the same shape as the pattern; and the slide rest that carries the cutter and tracer being made to slide along in the usual manner brings out the required copy of the pattern, one man being able to attend on several machines.

The Blanchard lathes employed in the workshops of the war department are variously constructed: in some the cutter and tracer

are both mounted on a transverse slide rest; in some they are suspended like a pendulum; in another, which is found to be a very superior arrangement, the tracer and cutter are mounted together on a rocking frame, the centre of motion being near the floor. By both the latter modifications the friction is greatly reduced, and the action is more delicate in tracing the exact outline of the pattern than with the slide rest motion.

A wheel fitted with cutters similar to that used in the Blanchard lathe has been employed with great advantage in forming different curves by means of a single instrument. This is done on the principle that if a piece of wood is passed under the cutting wheel in a line parallel with the axis of the wheel it will form a groove corresponding with the circle of the wheel's circumference; but if the wood is passed along the face of the cutting wheel it will produce a flat surface. Curves between these two extremes are obtained by adjusting the apparatus to intermediate angles.

The manufacture of scabbard linings affords another illustration of this copying principle. The wood is first cut roughly into shape by means of the endless band saw. The next operation is to shape one side of the exterior surface: to accomplish this the rough piece of wood is laid in a wooden holder which is susceptible of a longitudinal movement, and which by means of guides is constrained to describe a curve the same as that of the scabbard; this movement is made under a revolving cutter having the transverse shape of the scabbard; the two combined motions produce the required form. The other side is formed exactly in the same manner, the finished side being laid in a holder of the exact form, in order to have the two sides placed exactly opposite to each other. These two operations complete the exterior. The third operation is to cut out the receptacle for the sword: the wood already shaped externally is laid in a holder into which it fits firmly, this holder being made to move in the proper curve under a revolving cutter the shape of the sword. It is then placed in a fourth holder over a circular saw to widen the upper end in order to receive the thick part of the sword; after which the end is laid under a circular knife having a vertical movement by means of which the point is cut

to the proper shape. The accuracy of manufacture by this method is of course greatly superior as compared with the system of hand labour by means of which they have been made hitherto: also the rapidity of manufacture is greatly increased, two boys being able to produce 500 scabbard linings daily.

The same combination of movements is frequently arranged in a different manner, by means of which moulding or such work can be formed on the edge of irregular surfaces. The circular cutter of the required form is placed on the top of the vertical revolving spindle, as shown at A, Figs. 11 and 12, Plate 60. The piece of wood B to be operated upon is fixed to a holder C which has been cut to the shape in the longitudinal direction. The operation consists in pushing this holder against a fixed collar D surrounding the spindle; consequently a combination of the form of the holder and also of the cutter is transferred to the piece of wood.

In the Small Arm Factory at Enfield that intricate piece of mechanism, the gun stock, is produced entirely by machinery. It will be well understood how very difficult it is to make such articles perfect both in form and dimensions; it is comparatively easy to make things nearly correct, but to attain to perfect fitting from the machine involves conditions which are not ordinarily realised. With the machinery in question this absolute fit is secured at the rate of from 1000 to 1200 gun stocks per week, leaving only the exterior smoothing to be done by hand. The object of the present paper is not to describe the machines in detail, but only the principle of cutting; for it requires upwards of a dozen machines to produce a gun stock, each being differently arranged to suit its special operation; but the general principle in all is the same, and if understood may be readily applied in an infinite variety of ways for the performance of other operations.

The cutting out is effected by means of a revolving bit or drill E, as shown in Fig. 13, Plate 60, made in the required form and driven at a great velocity, 6000 revolutions per minute; this being kept very sharp is capable of producing a clean smooth hole, and if pushed against the wood F sideways, or the wood pushed against the drill, will cut its way in any direction. In order to guide the drill in cutting

out the required shape, there is placed alongside the gun stock F a hard steel pattern G of the required form; and upon the frame which carries the drill E there is fixed a dumb tracer H of the same external form as the drill. This tracer being connected with the same framework as the drill, and both having the same vertical or horizontal movements, it follows that if the tracer is brought into contact with the pattern G the drill will be brought into contact with the wood F and will drill its way accurately according to the truth with which the tracer is pushed round the pattern.

Owing to the intricate form of the gun lock, bits of different sizes are required to cut out the wood to fit it correctly: this is effected from a single pattern in the following manner. The machine is provided with a number of revolving bits of different dimensions, each accompanied by a tracer of exactly the same external form; and the machine is so constructed that each in succession can be brought into operation. At the commencement the larger bits are introduced; these clear out wherever the larger tracers can find an entrance into the pattern; and having done their part, the smaller bits are substituted, and at last a very delicate drill for touching off certain points too minute for its predecessors. Thus the whole operation is accomplished with the most rigid accuracy, and with a rapidity truly wonderful; for, including the fixing of the stock and the several changes of the drills, the whole may be performed under a minute.

The question naturally suggests itself, how can this accuracy be secured, seeing that the revolving drills are more liable to wear than the dumb tracers, and that such a condition must necessarily alter the dimensions of the recess produced by the drills, even if it give the proper shape. The method of compensating for wear is very ingenious and deserves to be generally known. The conical hole in the end of the running spindle into which the drills are fitted is made very slightly eccentric; the drill is also made eccentric on its shank to the same amount. Both the end of the spindle and the drill are graduated round the circumference. When the drill is new it is set to run truly central, by placing the two eccentricities opposite to each other, and thus to cut out its own diameter; but as by continued sharpening it necessarily wears, the time arrives when it requires to be altered in its

position in the spindle, by throwing it slightly out of centre; and owing to the high velocity with which it revolves, any disadvantage arising from the eccentricity in the working is not perceptible, while the accuracy and correctness of the fit are rigidly maintained.

Mr. J. Anderson exhibited a series of specimens showing the course of manufacture of the wood linings for scabbards that had been described in the paper, and of the wood sabots for loading cannon.

Mr. B. Fothergill thought the paper was a very interesting and valuable communication, and the machines described were remarkably complete and perfect, and very well designed for the special purposes for which they were intended. He had also seen several very ingenious American machines for working wood, though not carried to the complete extent of those described in the paper, and they might no doubt be available in our workshops and were well deserving of careful attention. The earliest application he remembered of machinery for the purpose of working wood was an attempt made by Mr. Roberts many years since to facilitate the ornamenting of table legs by means of a revolving cutter at a high velocity brought to bear on different portions of the work successively; he had succeeded in the object, but was prevented from bringing the plan into use by the prejudice of the workmen who opposed the use of the machine. The next application of machinery was to the manufacture of sticks for umbrellas, by having a hollow spindle revolving in two uprights, and at the end of the spindle a suitable cutter revolving with it, and the stick was then simply pushed up through the hollow spindle, and was quickly rounded throughout at the rate of two sticks per minute.

Mr. W. Fairbairn, having been connected with the construction of the engines for driving the machinery described in the paper, had witnessed the excellence and efficiency of the machinery, which was certainly most admirably contrived, and for which they were indebted to the energy and skill that Mr. Anderson had brought to bear on the extended applications of machinery to various works in connexion with the public service.

The Chairman could add his testimony to the great benefits that had resulted in the Government workshops from the improvements in the machinery effected by Mr. Anderson, and the great increase of efficiency in the workshops, where there was much to be seen and learnt applicable to other kinds of artificer's work. He proposed a vote of thanks to Mr. Anderson for his lucid and interesting paper, which was passed, and expressed a hope that he would give them a further communication on the subject.

Mr. J. Anderson said he would be happy at a future time to present some descriptions of other machinery that would be interesting to the Institution.

The following Paper, by Mr. John Hosking, of Gateshead, was then read:—

ON IMPROVEMENTS IN PUMP VALVES.

In the various arrangements and constructions of pumps for raising water and other fluids, the perfection of the pump depends mainly upon the valves, whether applied as fixed clacks or in the buckets; and their improvement has consequently attracted much attention for some years past, especially in connexion with waterworks for the supply of towns.

The writer's attention was more particularly directed to this subject about the year 1843, whilst engaged with Mr. Wicksteed at the East London Water Works, shortly after the introduction of the double-beat valve; this valve, of which a vertical section is shown in Fig. 1, Plate 61, was found to be for large pumps a most important improvement on the leather flap valves previously in use. The double-beat valve however was not free from objections, as it burdened the engine by requiring a pressure of 2 to 5 lbs. per square inch to lift the valve; and was also liable to get cross bound on the guides after becoming worn, and then to fall suddenly, producing a great shock on the engine and fracturing the valve. In its construction also there is the objection of the tortuous passage through which the water has to be forced; and further, however large the size, it has been found necessary to limit the lift to 3 or 4 inches and consequently to check the opening or water way, otherwise the fall or closing of the valve produced a concussion that was very detrimental to the valve itself as well as to the engine, pumps, and building. On the first introduction of the Cornish pumping engine for waterworks on a large scale it is questionable whether, with the valves then in common use, it could have been worked to advantage, had not the double-beat valve been devised to meet the difficulty which attended the percussive and rapid motion of the in-door or pumping stroke.

The evident requirements for pump valves are a large area of water way with a small amount of rise of the clacks, so as to diminish as far as possible the cause of concussion; and durability, which is secured by ease in opening and shutting with the smallest amount of beating action.

A variety of constructions of valves have been designed within the last few years, in which these objects were aimed at. Amongst the number may be instanced Mr. R. Hosking's annular valve, shown in Fig. 2, Plate 61; and Mr. R. Jenkyn's valve, shown in Fig. 3: both of these consist of a series of separate rings, each one falling upon the ring below, so that the top ring has to rise as much as the rise of all the others added together, in addition to its own rise. About the same time an ingenious valve was constructed by Mr. J. Simpson, shown in Fig. 4, in which a series of separate rings are also employed, each having two beats and falling upon a fixed seat so that the lift of each is independent of the others. In this valve the writer understands that the difficulties were similar to those experienced in the double-beat valve previously referred to; and that it was even more readily subject to derangement from small chips of wood or other obstructing substances that might accidently get into it.

In consequence of the experience of the difficulties and objections attending the different forms of valves at that time employed, the writer was led to the consideration of some other principle for the basis of construction; and in the course of enquiry the idea of the gills of fishes suggested itself, which open simultaneously a series of passages, giving free exit to the water, and closing again completely with great ease of motion. The first form of valve designed on this principle, and termed from that circumstance a "gill valve," is shown in Figs. 5 and 6, Plate 62, and consists of a series of annular seatings, each furnished with a leather ring divided into a number of small clacks: Fig. 5 is a vertical section of the valve, and Fig. 6 a plan, part showing the arrangement of the clacks in each ring, and part with the clacks removed showing the seatings; Fig. 7 is an enlarged section of one of the leather clacks. The metallic seatings for the leather rings are arranged in a pyramidal form, so as to afford a free entrance and exit for the water at each ring without interference from the adjoining rings; and by this arrangement the valve is capable of being constructed so as to have an area of discharge exceeding the area of the supply pipe, with as small amount of motion or lift of the clacks as may be desired. Each ring of leather forming the clacks is hinged along its inner

circumference by being simply nipped by the projecting edge of the seating above, as shown enlarged in Fig. 7, the whole being tightened and secured by the centre bolt. It should be remarked that this valve does not require any more room in the box or chamber than the ordinary valves, which is an important point in pit work for mining purposes. Figs. 5 and 6 show one of the gill valves lately made for the Kent Water Works, in which the area of discharge exceeds that of the suction pipe by 30 square inches or about 10 per cent.

These valves can be constructed either with separate leather clacks as above described, or with continuous rings of leather or india-rubber. With india-rubber rings the author has been more successful than he at first anticipated, as he doubted their durability and proper adaptation where high pressure was required; late experience has however shown that this doubt was unfounded. Figs. 8 and 9, Plate 63, show one of these valves constructed with india-rubber rings; Fig. 8 is a vertical section, and Fig. 9 a plan, part showing the successive rings in position, and part showing a plan of the lowest seating with the india-rubber ring removed; Fig. 10 is an enlarged section of one of the rings and the seating on which it rests. When india-rubber rings are used, the width of the spaces between the bars of the seatings is reduced and the bars made narrower, as shown in the plan, Fig. 9, the width of the spaces being made equal to the thickness of the india-rubber, which is proportioned to the height of the lift and varies from ·37 inch to 1 inch and upwards in thickness. It will be seen that in valves of this construction the size in no way regulates the lift or rise of the clacks or rings, and that the diameter is unlimited. About twelve months since one of these valves with india-rubber rings was supplied to the East London Water Works, of 4 feet 3 inches diameter, as shown in Figs. 8 and 9: this valve is now working admirably, having been in constant use since supplied, and from a late examination was found to continue as sound as when new, and absolutely tight, delivering 150 cubic feet at each stroke under a pressure of 125 feet head, working at the rate of 7 strokes per minute; the steam engine has a 100 inch cylinder.

Another modification of the same principle of valve is shown in Figs. 11 and 12, Plate 64, in which the rings are replaced by a set of

india-rubber balls, arranged in circles in the form of a pyramid as before, each ball falling into a separate conical seating, as shown in the plan, Fig. 12, and the enlarged section, Fig. 13. One of these valves was supplied to the Hull Water Works about forty years ago, and has been working in an occasional assistant pump during that time under a pressure of 160 feet head: one of the balls from this valve has been forwarded for the inspection of the meeting; and the author is informed that the weight taken out of the balance box of the engine when this valve was put in place of the previous double-beat valve amounted to 5 cwt. or about 8 per cent. reduction of the whole load upon the engine. It should be observed that a difficulty has been experienced in the application of these ball valves, when used as suction valves in pumps worked by the Cornish engine, on account of the rapidity of the in-door stroke and the valve not closing quite quick enough; this has led some engineers to prefer in such cases the leather valves previously described, in which the clacks are easily loaded according to their requirements. When the motion of the engine is uniform or regulated by a flywheel it is the opinion of all who have used the ball valves that they are equally applicable both as suction and delivery valves.

These valves have been in use somewhat extensively as air-pump buckets for steam engines, as shown in Figs. 14 and 15, Plate 64, for upwards of two years; and the author is not acquainted with any case where they have failed. This however is not more important than their entire freedom from that objectionable jolt or blow, which in some instances in marine engines not only shakes the whole vessel but even causes a limit to the speed at which the engines can be worked.

Figs. 16 to 19, Plate 65, show the arrangement of the same valves for the buckets of pumping engines. Figs. 16 and 17 are a vertical section and plan of a bucket fitted with rings of small leather clacks. Figs. 18 and 19 show a bucket furnished with india-rubber rings, constructed for a lift of 300 feet. Figs. 20 and 21 represent one of the common buckets at present in use, showing the large size of the clacks and the great amount of fall as compared with the valves shown in Figs. 16 and 18.

In these valves it will be seen from the drawings that each successive seating is made to act as a guard to the ring, clacks, or balls next below it, regulating the extent of lift; and the simplicity of construction, each seating fitting into the one below by a turned joint without bolts and nuts, the whole being secured by the central fastenings, renders these valves compact and free from liability to get out of order, whilst the great freedom of water passage and consequently small amount of motion required in the clacks or rings ensures their durability.

Mr. J. Hosking showed a specimen of a large pyramidal valve, 22 inches diameter, with six separate rings of leather clacks; also a model of another valve fitted with india-rubber rings; and specimens of an india-rubber ring and ball that had been long at work.

Mr. B. Fothergill enquired what kind of india-rubber had been found best suited for the valves; he had found when the greatest action came on one particular part some kinds of india-rubber were liable to break across at that point.

Mr. J. Hosking replied the material he used was Moulton's vulcanised india-rubber, and he found that was quite satisfactory in working; the only precaution in its manufacture was to make its specific gravity one half greater than water, to ensure the valve shutting properly. He exhibited a specimen of one of the india-rubber rings, 13½ inches diameter and ·62 inch thick, that had been three years in constant work in the air-pump bucket of a steam engine and had now been taken out for the purpose, the india-rubber not showing any signs of wear.

Mr. T. S. Prideaux had experienced much difficulty from variation in the quality of the india-rubber employed for the piston packing of the regulating cylinder in his furnace air-valve, and found it would not work well with some kinds of water, till he was enabled to obtain a uniform good quality of india-rubber for the purpose.

Mr. E. A. Cowper had used the white vulcanised india-rubber very successfully for a long time in air-pump valves, and found that quality was very durable and satisfactory; but some kinds of india-rubber he had known become brittle in work as had been mentioned. In the valves described in the paper, the idea of the original double-beat valve was quite departed from; namely that of having a much smaller area for the water to act against in opening the valve than the area of the passage when opened, the lift of the valve being much less than in old-fashioned valves. In these new valves the whole area was exposed to the pressure, and the area of passage was made so large as to require only a very small height of lift of the valve. This was certainly the best principle, as the important point was to ensure the valve always shutting itself before the return stroke commenced, and to prevent any risk of the valve being shut by the water in the return stroke, which caused a very severe concussion when working quickly or under heavy pressure. This object was best attained by reducing the distance that the valve had to fall, and the valves described in the paper appeared to be admirably adapted for this purpose from the large area of passage that they gave with a very small amount of lift; the ball plan was perhaps the most perfect arrangement, if the balls could be made to stand well. He had himself used with great success a modification that he had made of a metal ring valve, in which a large ring was at top and a small one at bottom, and both rings were fixed to a long tube sliding up a centre pin, thus guiding the rings so steadily that it was impossible for the valve to get into cross-winding, and so preventing all risk of its not closing promptly; these valves lifted only ·56 inch.

The Chairman asked what amount of lift was given in the largest sized valve that had been described in the paper.

Mr. J. Hosking replied the lift was limited to ·87 inch in the large 51 inch valve, which was the largest at present made on that plan, and the area of passage in that case was about two thirds of the full area of the supply main. The durability of these valves and the ease and perfection of their action was stated to be completely satisfactory wherever they were working; and their use was being extended for waterworks pumps, for which they were specially adapted,

as valves of very large size working under heavy pressure were now required. For mining purposes the advantage of this construction was not so much felt, as the diameter of the valves was much less; the india-rubber ring valve was then generally preferred, on account of convenience of repairs.

The CHAIRMAN observed that in the application of pump valves for working under a low head of water the loss from all sources bore a large percentage to the total work done; in fact the lower the column, the greater the percentage of loss. He had used india-rubber valves in some very large pumps for draining a dock, and the quantity of gravel that was drawn up by the pump without injury to the india-rubber was very remarkable. India-rubber had very great powers of resistance, and where it could lift freely its durability seemed almost endless; the only objection to it was its lightness, being so little heavier than water and wanting weight to assist in shutting quickly. The plan of ball valves appeared an excellent construction if it could be arranged to add weight to the balls, and this objection might probably be removed by making the balls with lead in the centre.

He proposed a vote of thanks to Mr. Hosking for his paper, which was passed.

The following Paper, by Mr. Edward Fletcher, of Gateshead, was then read:—

DESCRIPTION OF THE LOCOMOTIVE ENGINE SHED AND TURNTABLES AT THE GATESHEAD STATION.

In the arrangement of large Engine Sheds the important points requiring consideration are capacity and economy of construction, combined with facility of ingress and egress for the engines at all parts of the shed. In the shed forming the subject of the present paper, which is erected at the principal locomotive works of the North Eastern Railway at Newcastle-on-Tyne, an unusual number of engines had to be accommodated in one place; so many that five separate buildings of the ordinary polygon arrangement would have been required, entailing a very heavy cost of construction.

From the convenience of the polygon arrangement for access to all the engines, the same general plan was adhered to as regards the engine pits and turntables; which are arranged, as shown in the general plan, Fig. 1, Plate 66, in the same manner as if five ordinary polygon sheds had been constructed close together, in two rows alternating with each other, so that the lines joining the large turntables AA in the centre of each polygon form three equilateral triangles. By this arrangement of plan, a direct line of rails is obtained communicating from every turntable to each of the adjoining ones; and several distinct roads are obtained for entrance or exit at each of the turntables, one of them having five separate roads, while two of them have four, and the remaining two have three roads each. Then instead of having the expense of building that would have been involved by the construction of five separate polygonal sheds, requiring a long range of wall and an expensive construction of roof on account of the large span and polygonal form, the whole area has been enclosed by a plain rectangular wall, as shown by the diagram plan, Fig. 5, Plate 67, and covered in by five ordinary parallel roofs of moderate span, supported by four rows of columns running the entire length of the building, and falling in the intermediate spaces between the pits, without interfering with any of the lines of rails, as will be seen by the general plan, Fig. 1.

The result obtained is a covered area of 126,000 square feet, instead of 88,257 square feet which would have been the area of the five polygons, or an increase of 43 per cent. in area, with a reduction of 37 per cent. in the length of walling, which is 1476 feet in the rectangular building, instead of 2340 feet; the cost of construction being reduced in a considerably greater proportion from the simpler and cheaper description of work in the rectangular building as compared with the polygons.

The additional space obtained in the rectangular building, as shown by the shaded portion in the diagram, Fig. 5, is found of great utility and convenience for carrying on the minor repairs done in an engine shed, such as changing wheels, &c., which is here accomplished without occupying any of the lines used by the running engines. For this purpose strong lifting frames are fixed over the spare lines in those parts of the shed, as shown at BB in Fig. 1, fitted with gearing for lifting the engines. Fitters' benches are also erected in the open spaces of the shed, as shown at CC. At DD are fireplaces for warming the shed and lighting the engine fires.

Fig. 2, Plate 66, is a transverse section of the building, showing the five separate roofs, of which the three centre roofs are 65 feet span, and the side roofs 42 feet 6 inches, making the total width of the building 280 feet. The total length of the building as shown in the drawings is 450 feet; but only two thirds of this, or 300 feet, is at present built; the portion EE in the plan, Fig. 1, including two of the turntables, not being yet constructed.

Fig. 3, Plate 67, shows an enlarged transverse section of one of the 65 feet roofs. The principals are fixed at 12 feet 6 inches apart, and the purlins are trussed with wrought iron flitches, 4 inches by $\frac{1}{4}$ inch, with $4\frac{1}{2}$ by 4 inches wood. The principal rafters are constructed of two bars of channelled iron $4\frac{1}{2}$ inches deep by $1\frac{1}{2}$ inch wide on the flanges, with a $2\frac{1}{4}$ inch space between them, into which the ⊤ iron struts are fixed. The cast iron columns supporting the roof are fixed at 25 feet apart and connected by cast iron girders; and at F in the plan, Fig. 1, one of the columns is omitted for the convenience of the oblique lines of rails, and a wrought iron girder of 50 feet span is introduced, which is shown in Fig. 4, Plate 67.

A plan of one of the engine turntables is shown in Fig. 6, Plate 68, and a longitudinal section in Fig. 7, with a transverse section at the centre in Fig. 8, and a section at the end in Fig. 9. The table is 42 feet diameter, and consists of two main wrought iron girders GG, 3 feet deep at the centre, and 2 feet deep at the ends. These girders are secured together by a cast iron cross H, which fits upon the fixed centre pin I, by a cylindrical socket extending the whole depth and turning freely upon the pin. The centre pin is of wrought iron, 9 inches diameter, and is fixed into a socket 2 feet deep in the pedestal K bolted down to the foundations; the pedestal is shrunk upon the pin, which is then secured by a key. The bearing for the table is taken at the top of the fixed centre pin I, by a short steel pin L, 6 inches diameter, which revolves in a socket 5 inches deep in the top of the fixed centre pin I. The bottom of the pin L is rounded at the edge and turns upon a steel plate $1\frac{1}{2}$ inch thick at the bottom of the socket. The pin has a flange at the top carrying a cast iron cap, from which the whole table is suspended by six bolts taking hold of the cast iron cross H, the bolts giving the means of adjusting the level of the table.

The outer ends of the girders are fitted with sliding wrought iron wedges, which are moved by the handles M, and when pushed out rest solid upon cast iron chairs fixed upon the outer foundation curb at the end of each line of rails, and support the ends of the girders whenever an engine is being moved on to or off the table. A pair of safety rollers N is added at each end, running upon a circular rail O, but not in actual contact with the rail in the ordinary working of the table, being applied only as a precaution to prevent strain from the weight not being balanced on the table or in case of accident to the centre pin.

An engine and tender is readily turned upon the table by two men pushing at the end, without requiring gearing; the weight is so nearly balanced upon the centre pin that the rollers at the ends do not take any appreciable weight in regular working; and the due placing of the engine on the table for this plan is sufficiently ensured in practice by the circumstance that any neglect in this respect would increase the resistance to be overcome in turning the table.

An important advantage in this construction of turntable is the great facility for examining and keeping in order the only part that is subject to wear, namely the steel centre pin; this is readily done by fixing the sliding wedges at the end of the girders, when the table becomes a rigid portion of the line of rails, and the steel centre pin is taken out by simply unscrewing the six nuts, and the socket is readily examined being close to the top of the table. These turntables have now been two years in constant use, and have given entire satisfaction, no attention having been required beyond ordinary oiling, and only one of the steel centre pins having required to be taken out for examination during the whole time.

Mr. E. A. Cowper observed that the large square roof was a decided improvement over the polygonal roofs, as the construction of parallel roofs of moderate span was certainly the cheapest mode of covering a given area, and the large polygon roofs were very costly to make. The advantage in increase of covered area and diminution of cost was an important gain, and every square yard of room was so valuable in an engine shed that it was very useful to get a large space enclosed and covered as had been done in this case.

The Chairman remarked that the paper read was a valuable and very desirable class of paper, giving the description of a local subject that could be examined on the spot by the members after the meeting.

He proposed a vote of thanks to Mr. Fletcher for his paper, which was passed.

A special vote of thanks was moved by Mr. E. A. Cowper, seconded by Mr. B. Fothergill, and passed, to the Local Committee and the Local Secretary, Mr. J. A. Haswell, for the active exertions and excellent preparations they had so kindly made for the purpose of the meeting.

The CHAIRMAN replied, as Chairman of the Local Committee, that it had been a very pleasing duty that they had performed, and they felt amply rewarded by the complete success that had attended the meeting.

The Meeting then terminated; and after the meeting the Members visited the North Eastern Railway Locomotive Works and the new large Engine Shed at Gateshead; also the High Level Bridge carrying the railway across the valley of the Tyne from Gateshead to Newcastle, at the height of 112 feet above the water, with a carriage road underneath the railway, the bridge consisting of six openings of 120 feet span each, constructed of trussed cast iron arched girders. A number of engineering and manufacturing establishments in the neighbourhood were also thrown open for the inspection of the Members and their friends.

In the evening a large party of the Members and their friends dined together in celebration of the first Meeting of the Institution in Newcastle.

On the following day an excursion took place of the Members and their friends by railway to the New Docks at Jarrow in course of construction by the North Eastern Railway, where the large staiths for shipping coal, and the wrought iron gates to the two entrance locks, 80 feet and 60 feet in width of opening, were shown by Mr. Harrison. The three coal jetties are constructed on a new arrangement, with eight parallel lines of railway projecting into the docks at right angles to the quay wall, the two centre lines of each jetty projecting 500 feet and the other lines projecting less and less on each side, allowing of ten vessels being loaded at once at each staith, five on each side; the drops are constructed for discharging two 8 ton coal wagons at each, with self-acting inclines laid at 1 in 100 in both directions, for bringing the loaded wagons and removing the empty ones.

The Members then proceeded by railway to the Sunderland Bridge, where the works in progress for the reconstruction of the bridge under his direction were shown by Mr. Robert Stephenson. The original bridge, one of the earliest and most celebrated examples of cast iron bridges of large span, constructed by Mr. Burdon in 1796 over the River Wear for connecting Sunderland and Monkwearmouth, consisted of six cast iron arched ribs, forming an arc of a circle of 237 feet span and 33 feet rise, with a clear height of 99 feet above low water; the ribs were of very light and open construction, only 5 feet deep throughout and 4 inches thick, fixed at 6 feet distance apart and connected together by hollow pillars of cast iron placed horizontally; each rib was constructed in separate short segments, 2 feet 4 inches long, connected together by six continuous longitudinal wrought iron bars, $3\frac{1}{2}$ inches deep and $\frac{3}{4}$ inch thick, let into groves on each face of the ribs and secured by six bolts in each segment. In consequence of the insecure and inconvenient condition of the bridge, an Act of Parliament for repairing it was obtained in 1857, and the works were commenced early in the present year. The most important defect of the original structure was the absence of diagonal bracing; which, although in some measure rectified by an ingenious application of cast iron crosses between the ribs by Mr. Grimshaw of Sunderland, had still allowed of the whole of the ribs becoming curved laterally out of their vertical planes to the extent of as much as 16 inches. The bridge is now being strengthened by the addition of three wrought iron rectangular tubular arches, of the same curvature as the cast iron ribs and 5 feet 2 inches deep by 6 feet wide; the top and bottom plates being $\frac{1}{2}$ inch, and the vertical sides $\frac{3}{8}$ inch thick. These tubes are fixed in the alternate spaces between the original ribs, the old bracing being removed, and the ribs securely bolted to the tubes, so as to cause the whole to compress together, the original external form of the ribs being thus preserved; and in order to secure a perfect diagonal bracing at all points, the arch tubes are connected together throughout at the top by boiler plates $\frac{3}{8}$ inch thick, flush with their upper surfaces. The inclination of the road over the bridge on each side is also improved from about 1 in 17 to 1 in 50, by raising up the spandrils of the

arch over the haunches; and the width is also increased about 10 feet by causing the footpaths to project on cantilevers.

On the occasion of the Members of the Institution visiting the Sunderland Bridge, the following address was presented by the workmen engaged upon the works of the bridge:—"Gentlemen,—We, the workmen employed upon Sunderland Bridge, beg to welcome the engineers of England; whose works have made this country of ours famed over the habitable globe. This bridge when completed we trust will be both an ornament to the borough of Sunderland, and a lasting monument to the skill of practical engineering. We also trust our labours, so far as they have progressed, will meet with your approbation; and we are proud of this opportunity being afforded us of testifying our admiration of the eminent men who compose the Institution of Mechanical Engineers." Mr. Stephenson in reply expressed his gratification at the address presented to the Institution, and added that there were no members of society for whom he had a higher respect than for industrious and intelligent workmen. It was to them that the engineer was indebted for the full and efficient realisation of his conceptions, which, however good they might be, must largely depend upon the skill of the workman for their success. The progress made in the higher branches of engineering during the last thirty years might be attributed in a great degree to the improved skill and intelligence of the workmen. The advance of mechanical science and its application to useful purposes must always go hand in hand with the skill and also with the comfort of the working classes. He could not refer to a better example in proof of this than the bridge upon which they were now standing. The alterations and improvements which the workmen were so admirably carrying on could not have been executed at the time when the original bridge was designed. If the engineer therefore had even designed the bridge as it was now intended to be made, his mental labour would have been vain and useless, for there was not sufficient skilled labour in the country to realise such an idea. He merely took this bridge as an appropriate example on the present occasion, because it was a work they were now carrying out under his own direction; but it was only necessary to look around, and we met everywhere with engineering

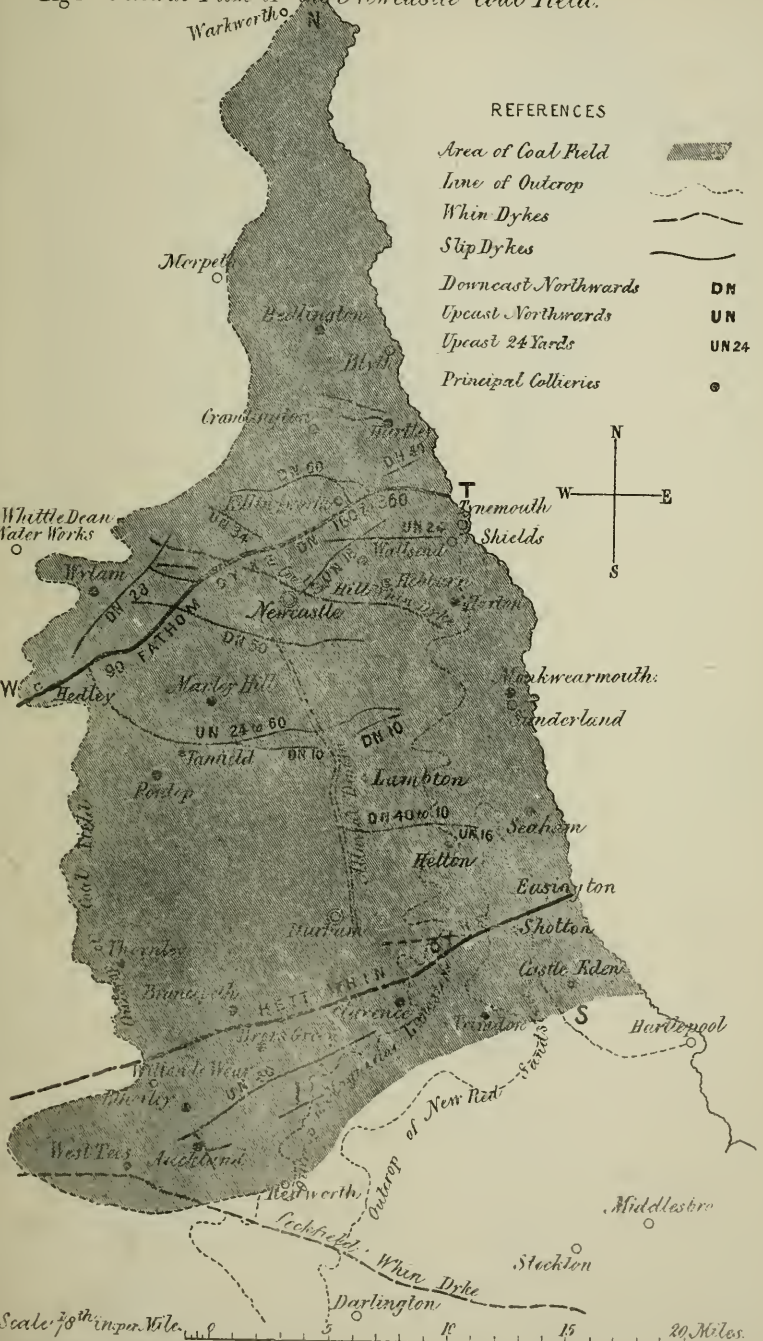
works to which the remarks he had just made applied in the strictest manner; and reflection on such subjects taught us to feel that skilled labour was the great fulcrum upon which all our social progress depended, and that the success of this progress was just in proportion to the skill of the labour brought to bear upon the great works so thickly scattered throughout our country.

The Members having been hospitably entertained by Mr. Lawton at the works of the bridge were then taken in the steamer of the River Wear Commissioners, which was kindly provided for the occasion, down to the mouth of the river and into the sea entrance of the Sunderland New Docks; where the works of the docks were shown by Mr. Meik, and the hydraulic machinery was seen, constructed by Mr. Armstrong for opening the large sluices employed for scouring the channel at the south outlet, and for working the dock gates and large drawbridge. The whole machinery is worked by an accumulator having a ram 2 feet diameter and 17 feet stroke, loaded with a weight of 100 tons, giving a working pressure of 495 lbs. per square inch, charged by a 30 horse power horizontal pumping engine. The sluices are in two sets of four each, situated on each side of the outer gates, each sluice having an opening of 8 feet 10 inches width and 7 feet height; they are rapidly opened by means of the hydraulic pressure, requiring only about half a minute, and open a total area of 495 square feet, which is done at low water, causing the sudden rush of a large body of water from the higher level within the gates, which effectually scours the entrance channel, and keeps it open to the sea. The large drawbridge, which is 100 feet span and 14 feet wide, slides laterally upon rollers and is traversed across the opening of the dock entrance by a pair of horizontal hydraulic cylinders 10 inches diameter with multiplying chains, working on one side under the projecting tail of the drawbridge that balances the overhanging portion; and the whole platform weighing 150 tons is then lowered down 16 inches on to a solid bed by means of a pair of vertical hydraulic cylinders 17 inches diameter, which serve to raise it again when the bridge has to be opened; the time of opening or closing the bridge is little more than a minute.

The party then proceeded by the line of the old Durham and Sunderland Railway to Hetton Colliery, where they were shown by Mr. Nicholas Wood the works of the colliery, and the large ventilating furnace and the arrangements for ventilation of the workings. One of the original "Iron Horses" of Mr. George Stephenson was also seen at work, with vertical cylinders fixed in the top of the boiler, still in regular work, drawing a train of chaldron coal wagons from the colliery to the main line of the railway. The Hetton colliery has a larger quantity of air supplied for ventilation than any other in the country, amounting to 250,000 cubic feet per minute drawn through one upcast shaft by means of four large ventilating furnaces at the bottom of the shaft, with a consumption of 11 tons of coal slack per day of 24 hours. The upcast shaft is 145 square feet area and 900 feet depth; and a current of air is constantly maintained in it at a velocity of 30 feet per second, supporting a column of 2 inches of water. A small portion of the upcast shaft, about one fourth of the area, is employed for raising coals, but not partitioned off from the rest of the shaft.

After visiting Hetton Hall, where they were most hospitably entertained by Mr. Nicholas Wood, the Members returned by railway to Newcastle and to the South.

Fig. 1. *General Plan of the Newcastle Coal Field.*



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NEWCASTLE COLLIERY WORKING.

Fig. 2. *Section of Newcastle Coal Field, from Tynemouth to Hedley Fell, T to W.*

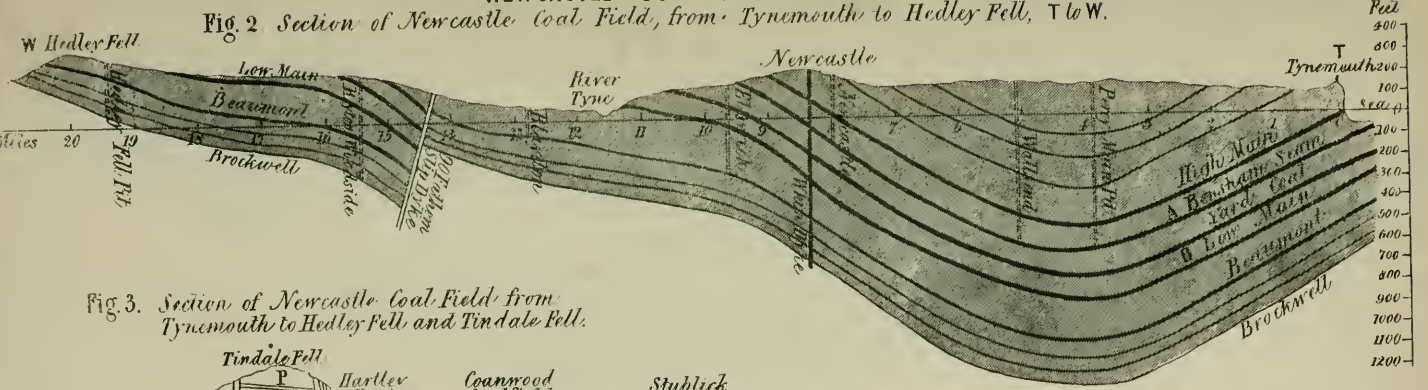

Fig. 3. *Section of Newcastle Coal Field from Tynemouth to Hedley Fell and Tindale Fell.*

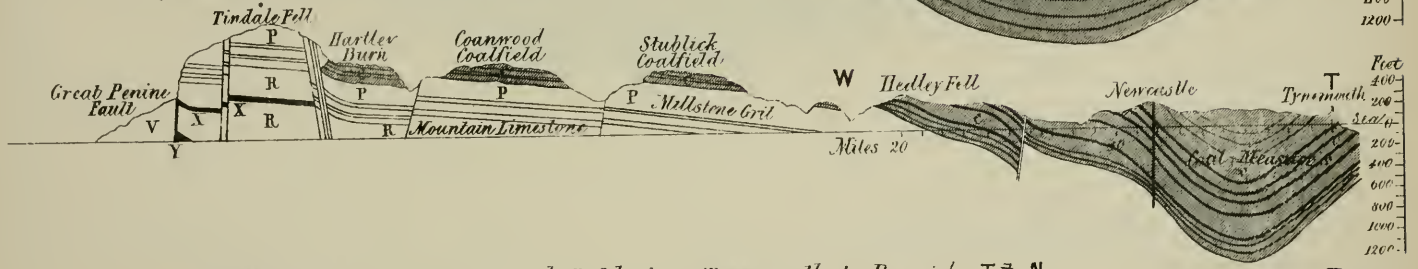

Fig. 4. *Section of Newcastle Coal Field from Tynemouth to Berwick. T to N.*

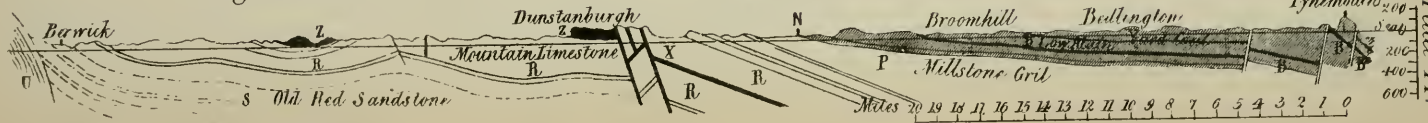

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Fig.5. *Section of the Newcastle Coal Field from Tynemouth to Castle Eden, T to S.*

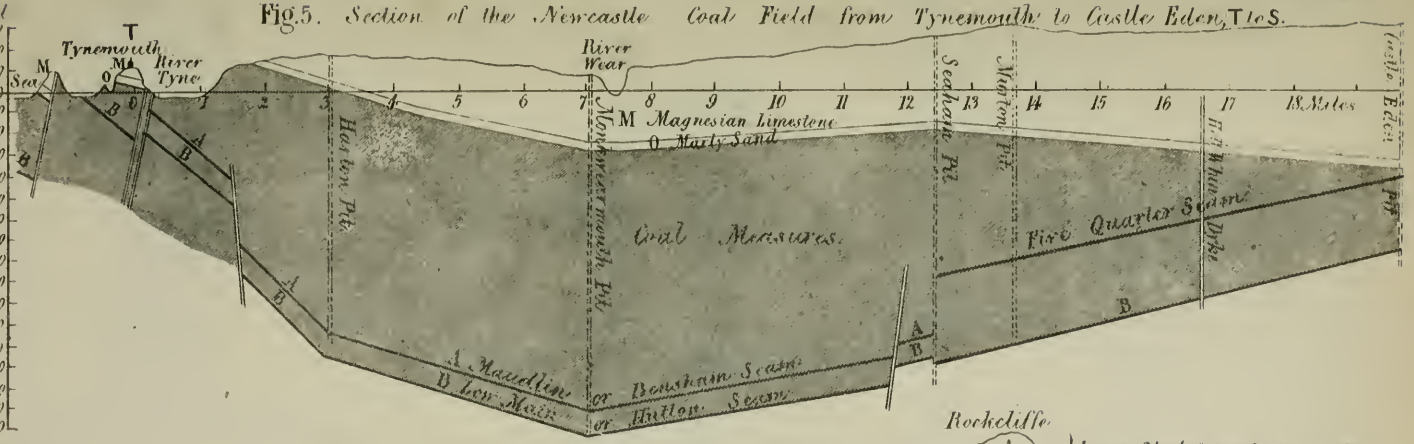

Fig.6. *Section of the Cleveland Ironstone District, Commencing about 13 miles South of Castle Eden.*

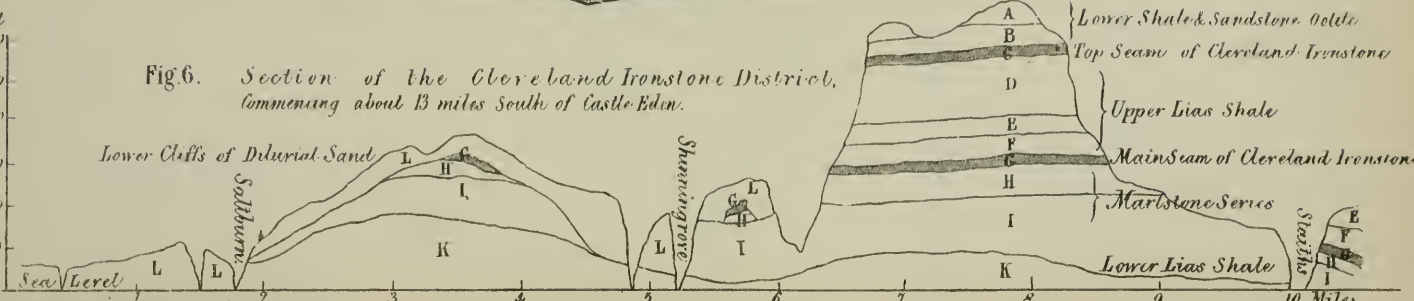

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Plate L.

Coal Cutting Machine

Fig. 7. *Side Elevation.*

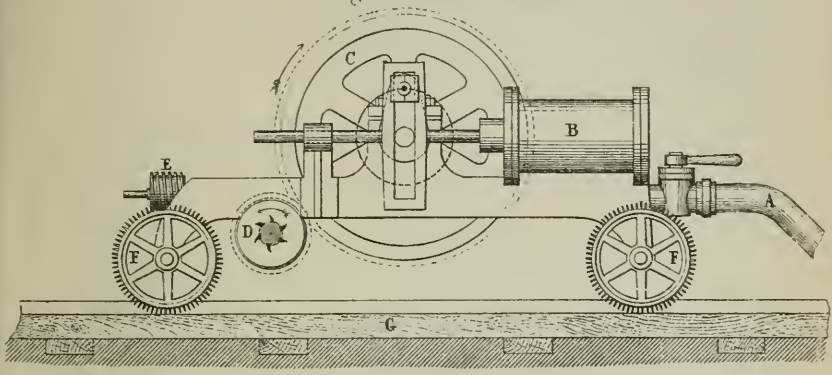


Fig. 8. *Plan.*

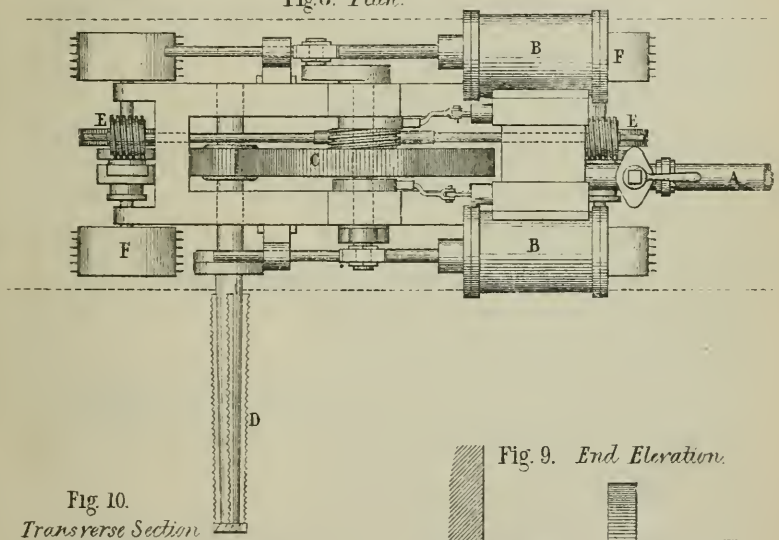


Fig. 9. *End Elevation.*

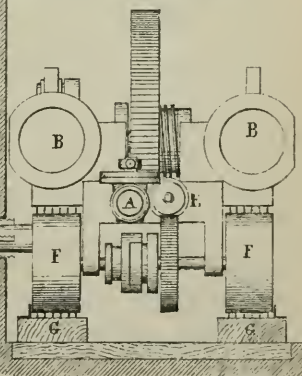
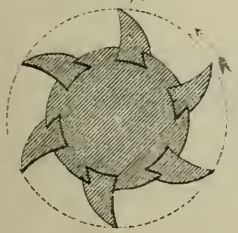


Fig. 10.
Transverse Section of Cutter
Scale 1/4th.

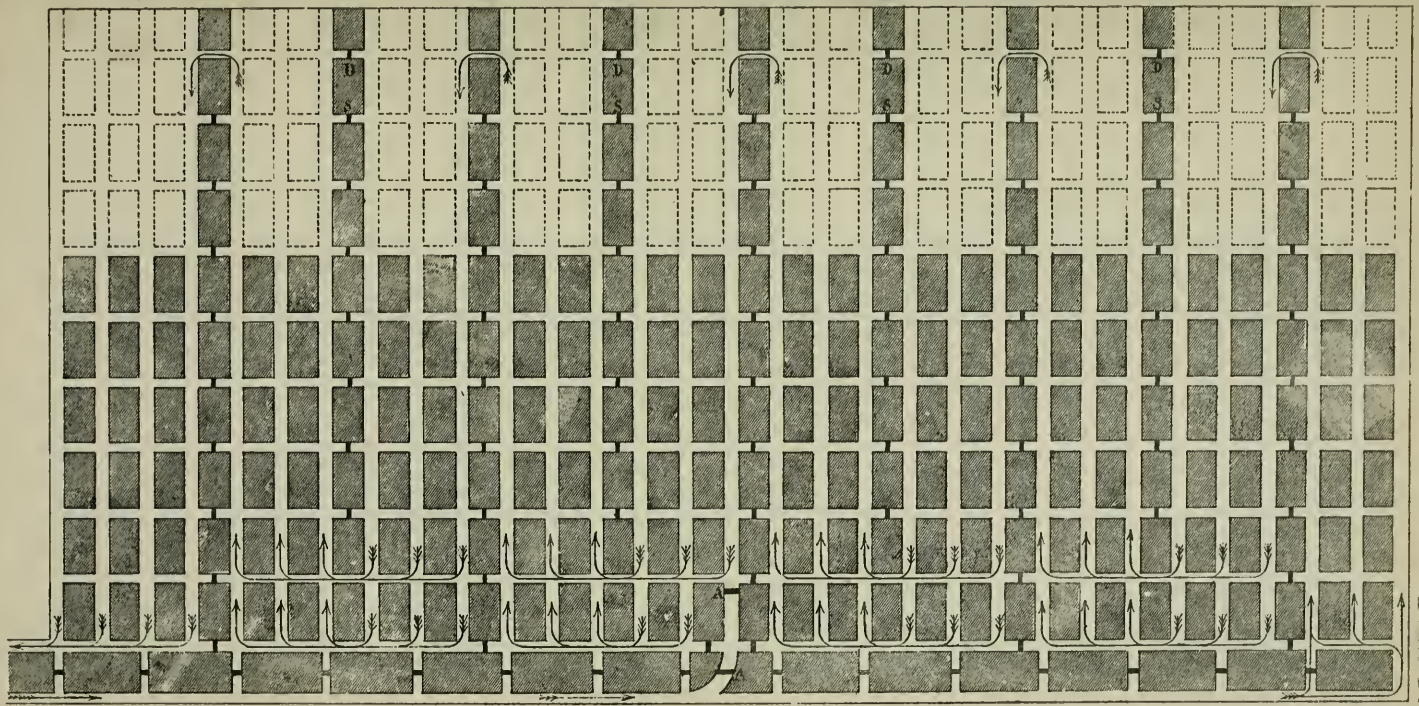


Scale 1/24th.

Ins. 12 6 0 1 2 3 4 Feet.

(Proceedings Inst. M.E. 1858. Page 177.)

Fig. 11. *Plan of Pillar and Stall Working, with Pillars being partially removed.*

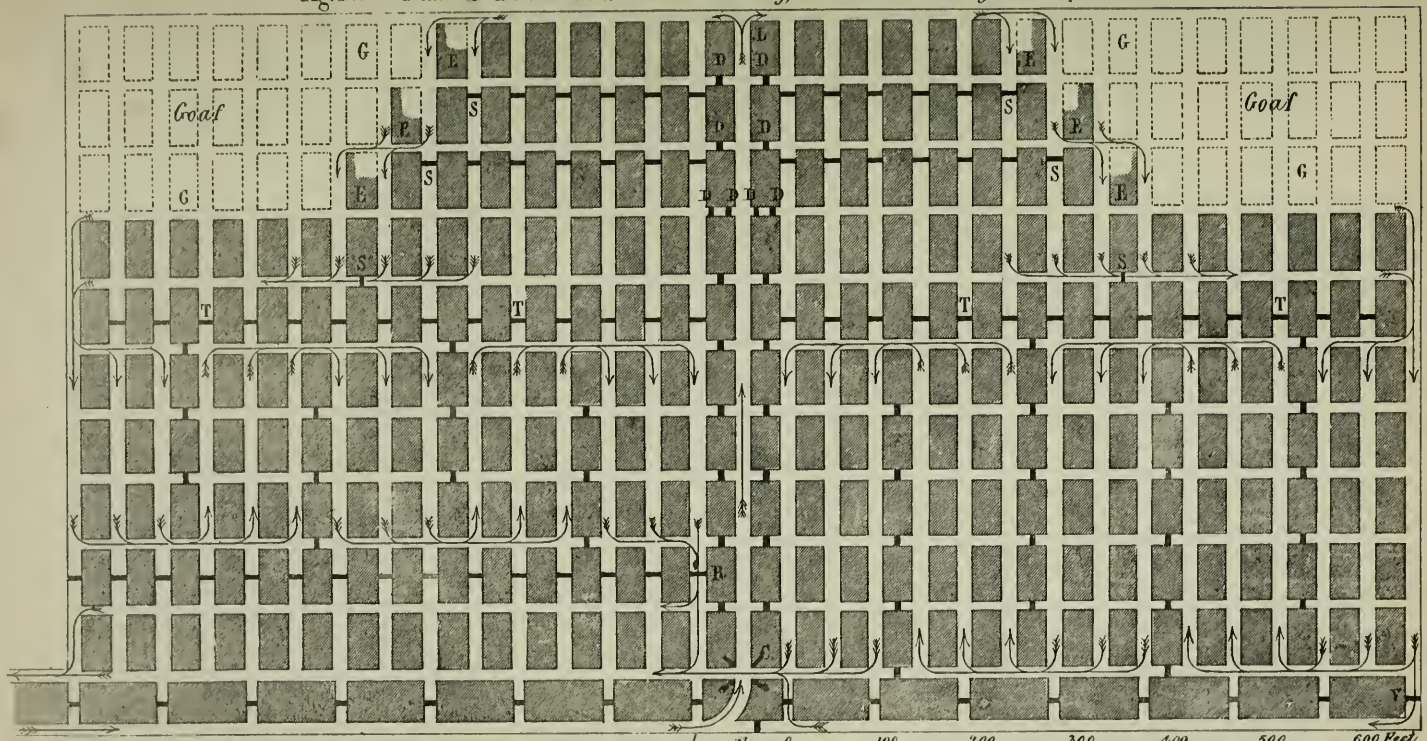


(Proceedings Inst ME. 1858. Page 177)

Plate 47.

NEWCASTLE COLLIERY WORKING.

Fig. 12. *Plan of Pillar and Stall Working, with Pillars being entirely removed.*



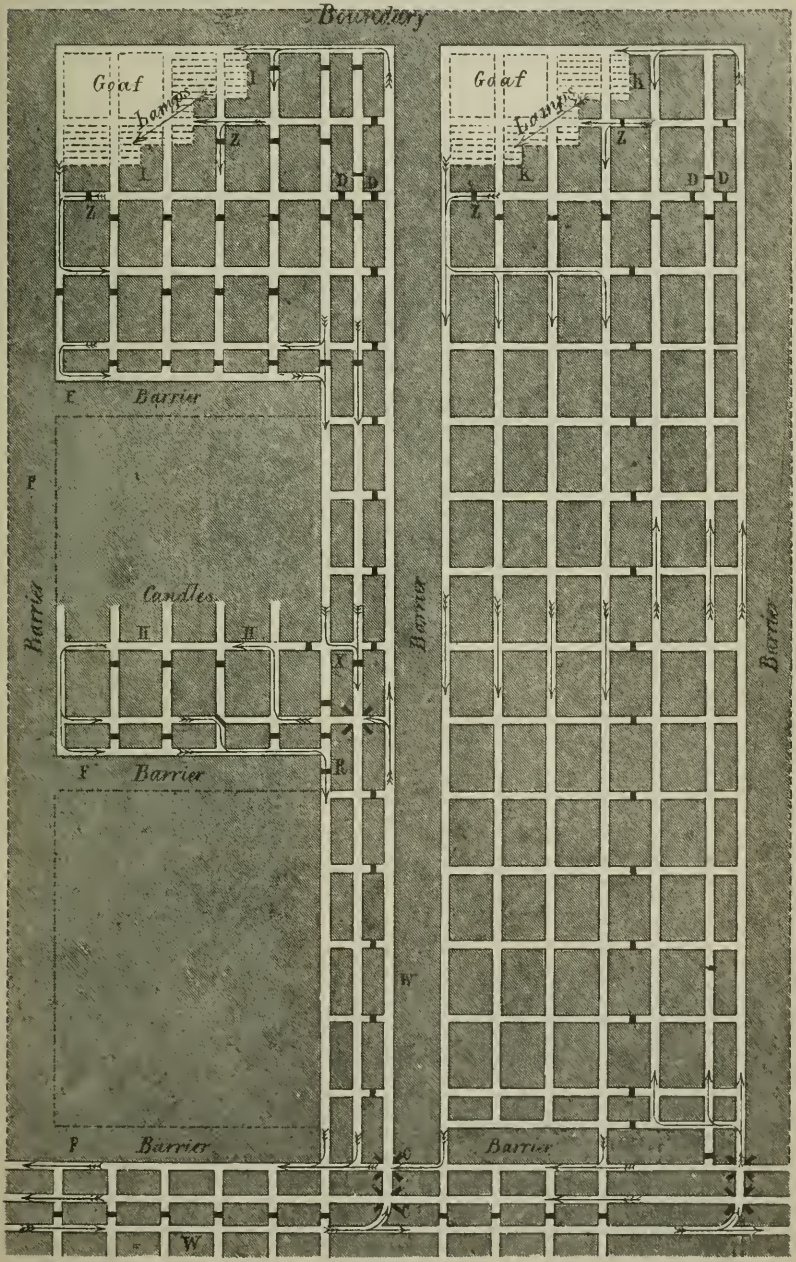
(Proceedings Inst. M.E. 1858 Page 177)

Scale 1/2500.th

Plate 48.

Fig. 13 *Plan of Panel Working. First Mode.*

Fig. 14. *Plan of Panel Working Second Mode.*


Boundary
Goaf
Goaf
Barrier
Barrier
Barrier
Barrier
Barrier
Barrier
Barrier
Barrier
Candles
Barrier
Barrier
Barrier
Barrier
Barrier
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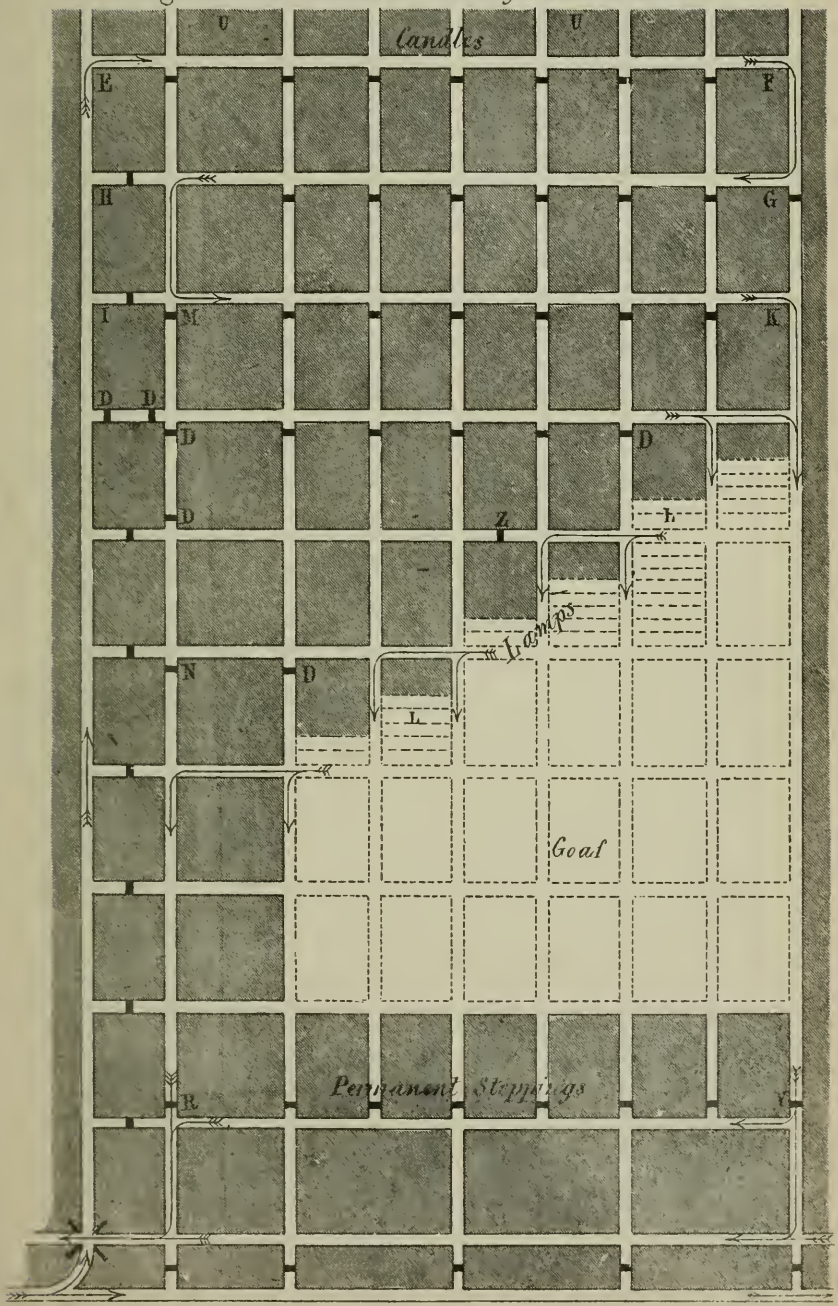
Barrier
Barrier

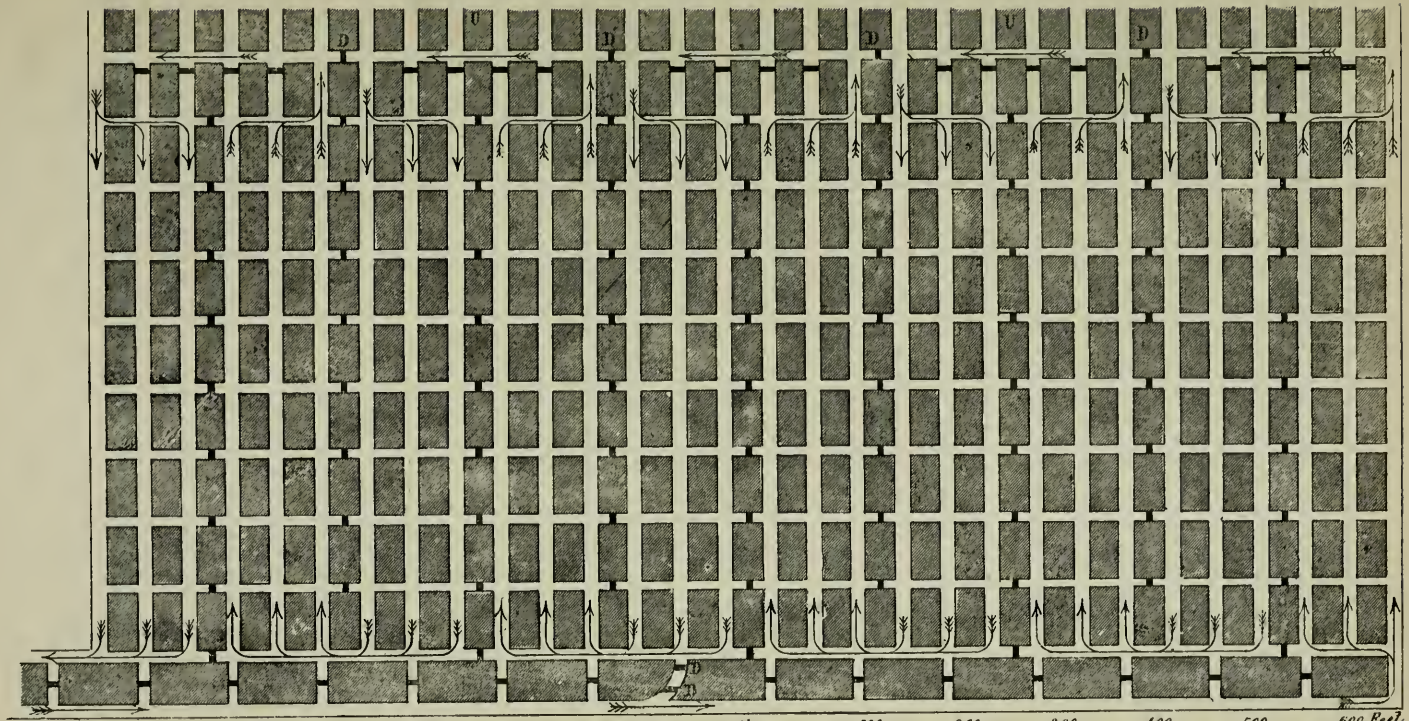
Fig. 15. *Plan of Panel Working, Third Mode*



(Proceedings Inst. M.E. 1858. Page 177)

Scale 1/2500th

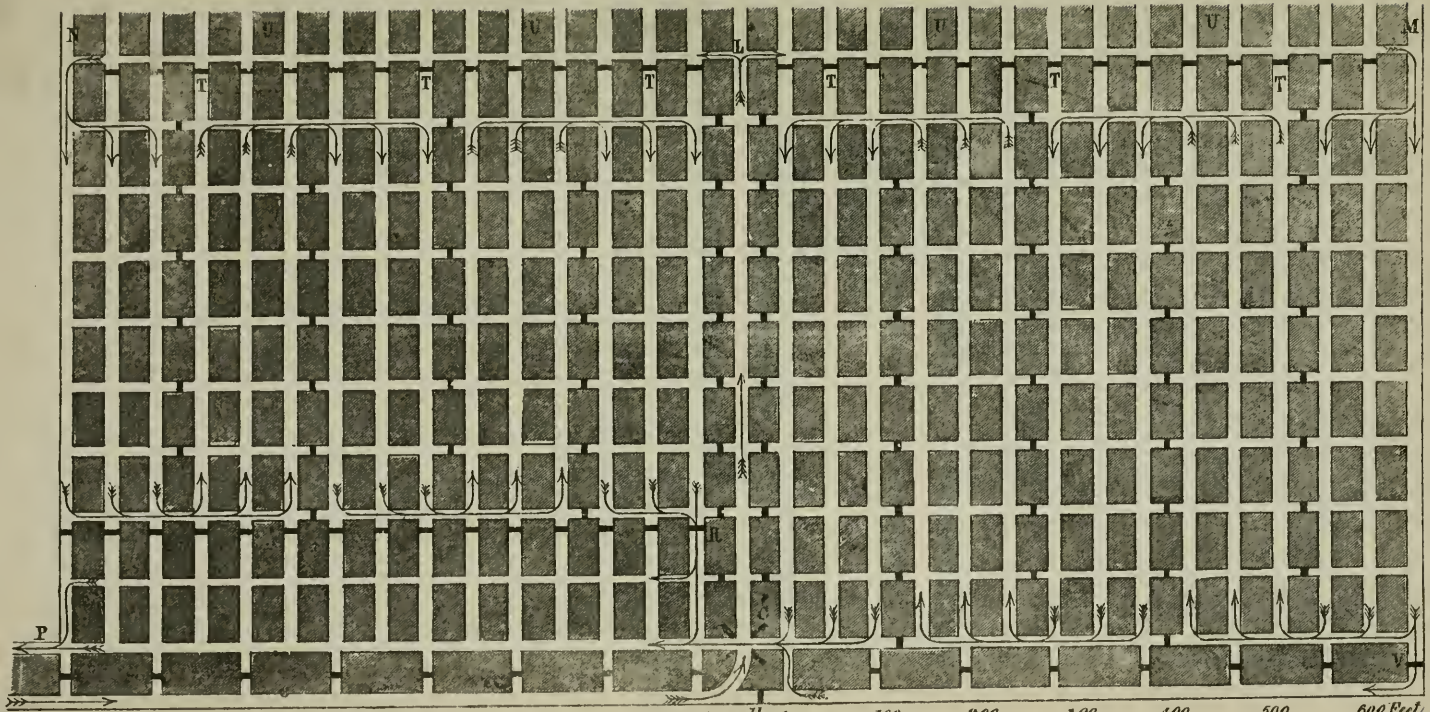
Fig. 16. *Plan of Early Mode of Ventilation with Doors*



(Proceedings Inst. M.E: 1858. Page 177)

Plate 51.

Fig. 17. *Plan of Improved Mode of Ventilation with Regulators.*



(Proceedings Inst. M.E. 1858. Page 177.)

Plate 52.

Fig. 18. *Ventilating Furnace at Hetton Colliery.*

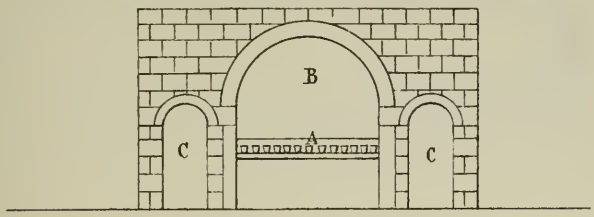


Fig. 19. *Plan of Furnace.*

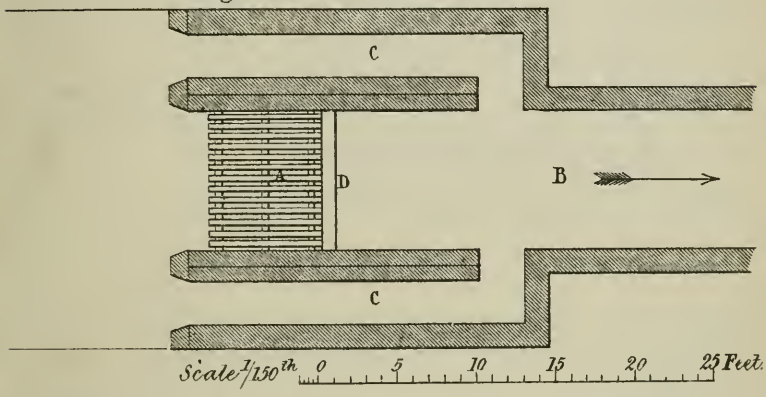
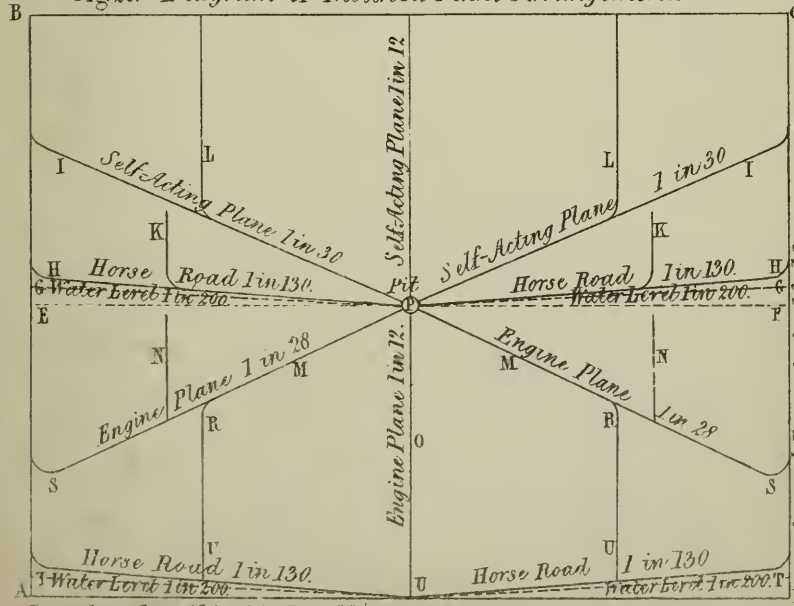


Fig. 20. *Diagram of Inclined Plane Arrangement.*



(*Proceedings Inst. M.E. 1858. Page 177.*)

Fig. 21 *Original Steel Mill.*

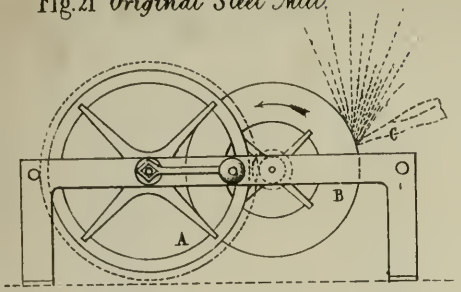
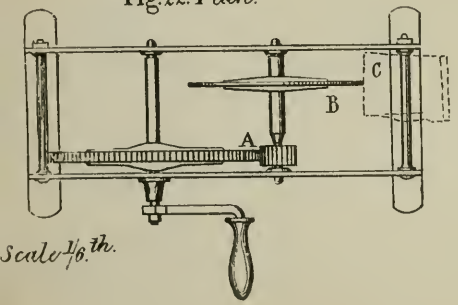


Fig. 22. *Plan.*



Scale 1/6th.

(Proceedings Inst. M.E. 1858. Page 177.)

Safety Lamps

Fig. 23.
Davy Lamp.

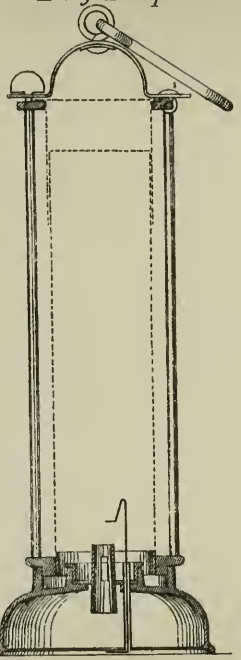


Fig. 24.
Stephenson Lamp.

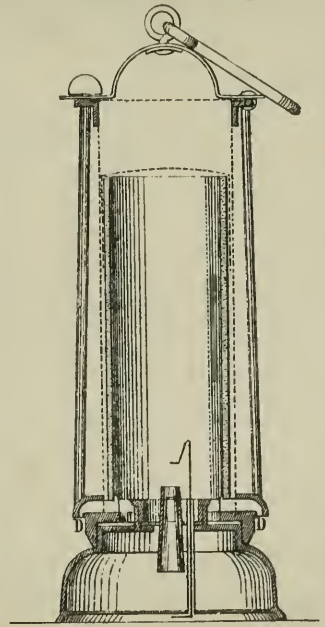


Fig. 25.
Clanny Lamp.

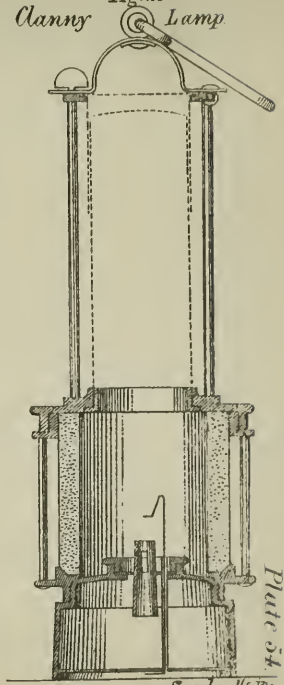


Plate 54

Scale 1/3rd

Safety Cage for Mines.

Fig. 26. *Side Elevation.*

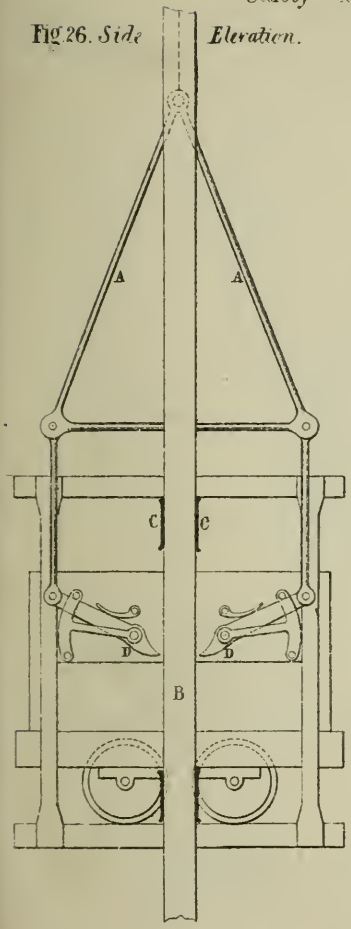


Fig. 27. *End Elevation.*

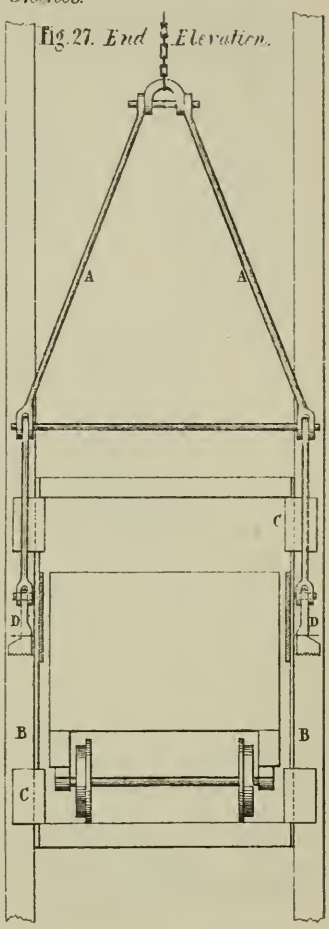
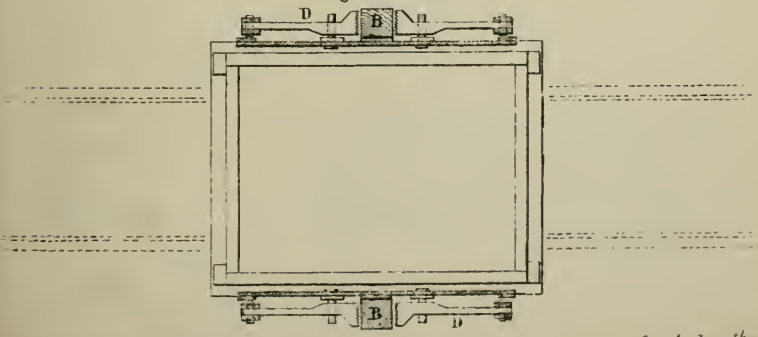


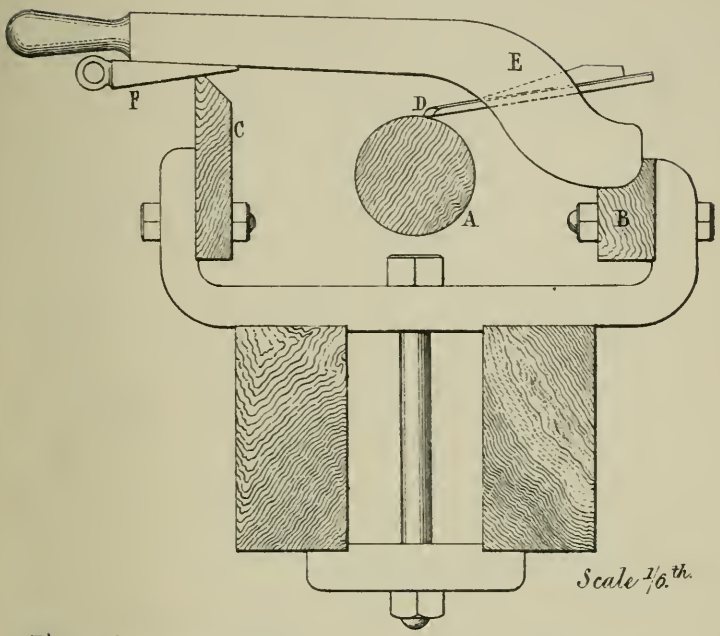
Fig. 28. *Plan*



Proceedings Inst. M. E. 1858 Page 177.

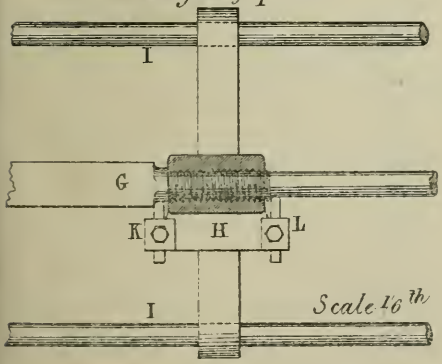
Scale 1/24th

Fig. 1. *American Copying Lathe.*



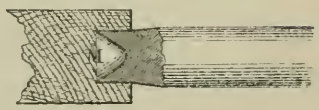
Scale 1/6th.

Fig. 2. *American Lathe for turning long poles.*



Scale 1/6th

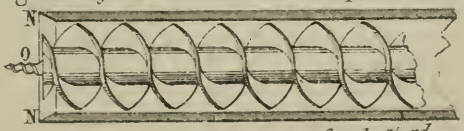
Fig. 3. *Lathe Centre for turning wood.*



Scale 1/3rd.

Fig. 4.

Fig. 5. *Augur and Box Chisel for square holes.*

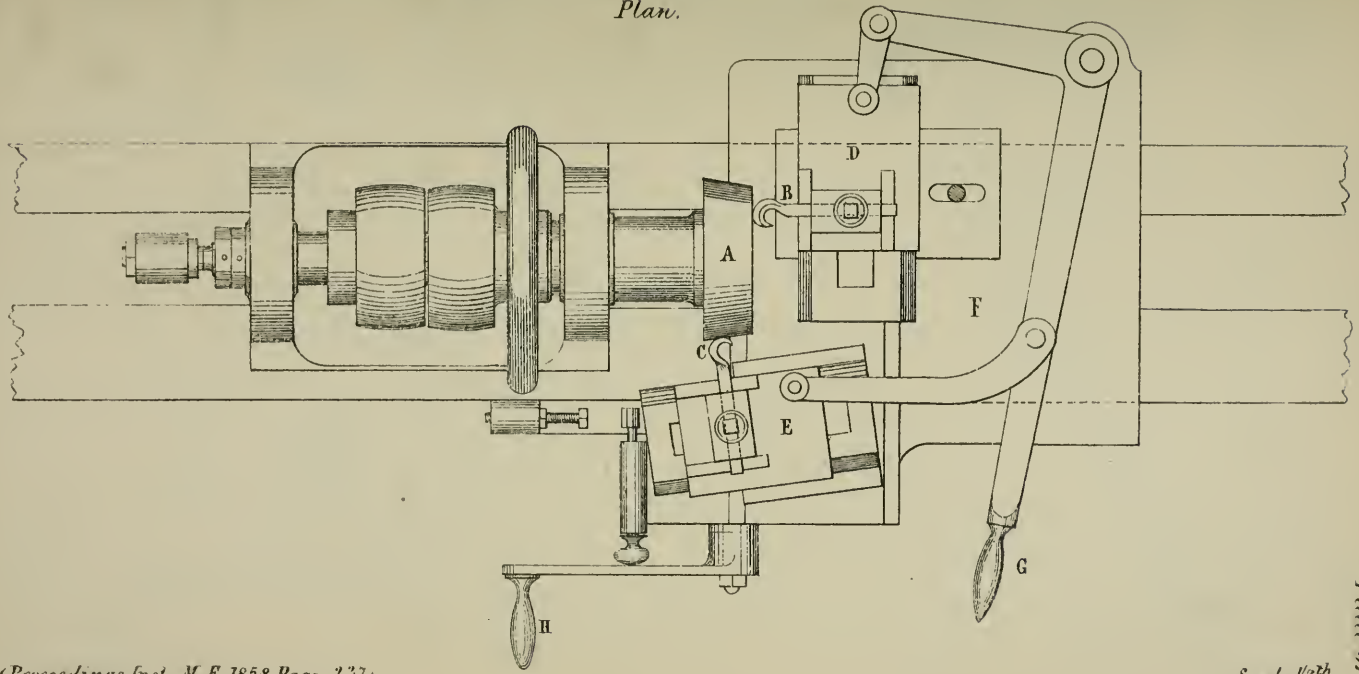


Scale 1/3rd.

(*Proceedings Inst. M.E 1858. Page 237.*)

Fig. 6. *Lathe for Turning Sabots.*

Plan.



(Proceedings Inst. M.E. 1858 Page 237.)

Scale 1/8th

Plate 57.

Fig. 7. *Lathe for Hollowing Sabots.*

Plan.

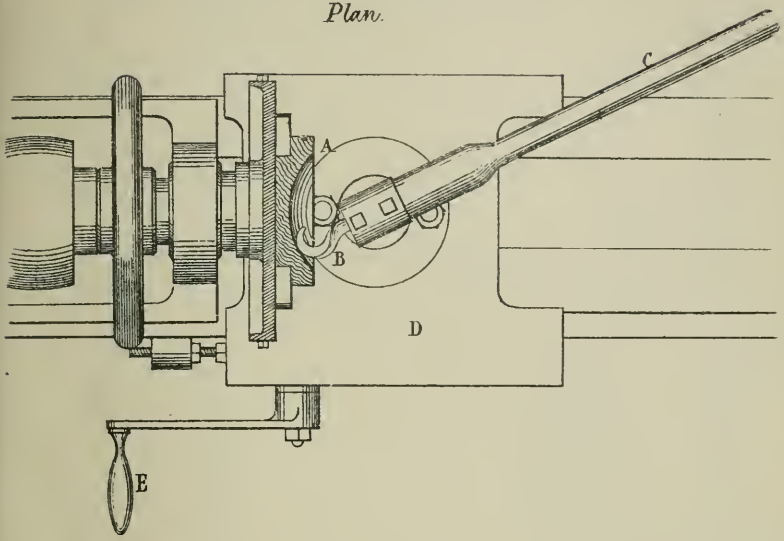
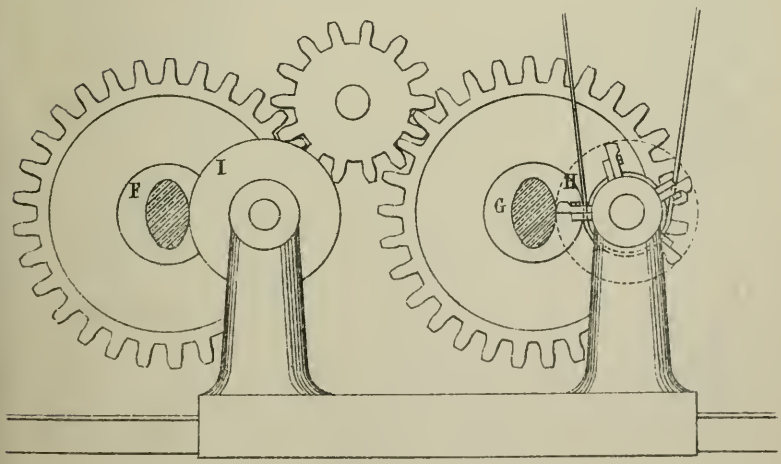


Fig. 8. *Blanchard Turning Lathe.*



Scale 7/8.th.

(Proceedings Inst. M.E. 1858. Page 237.)

Fig.9. *Machine for making Wood Plugs of Minie bullets.*

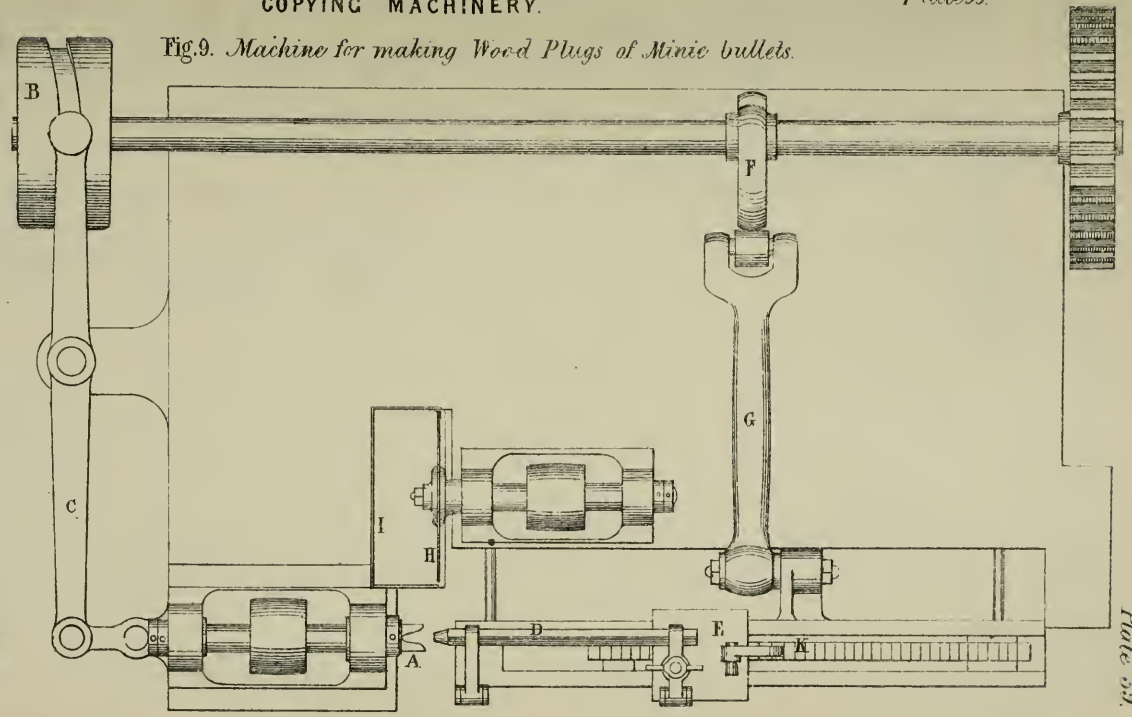
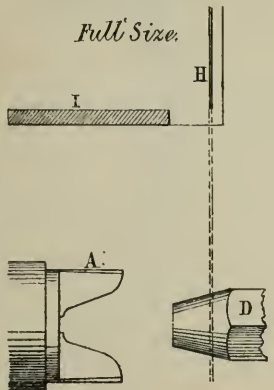


Fig.10.
Detail of Cutter.
Full Size.



(Proceedings Inst. M.E. 1858 Page 237)

Scale 1/4th.

Fig. 11. *Machine for Edge Mouldings.*

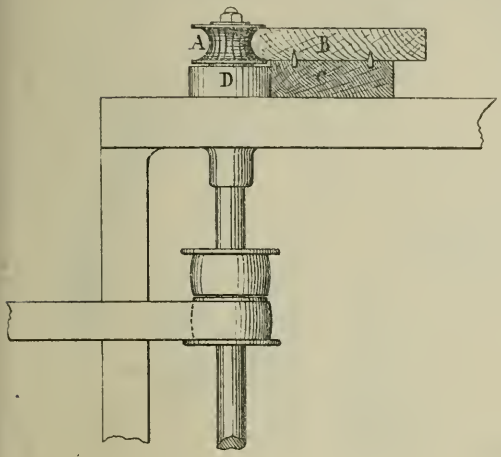


Fig. 12. *Plan.*

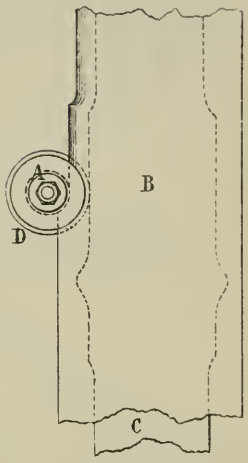
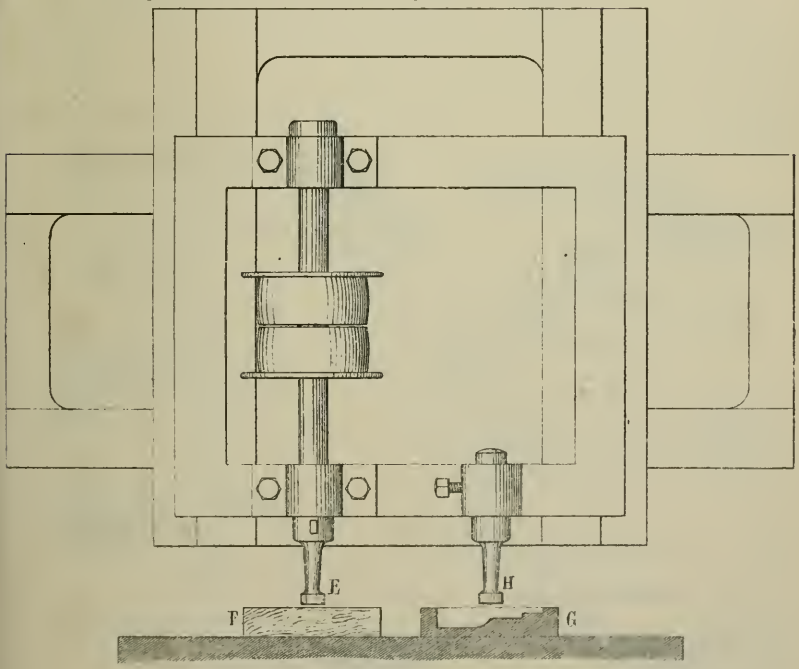


Fig. 13. *Machine for Cutting Gun Stocks.*



Scale ¼th.

(Proceedings Inst. M. E. 1858 Page 237)

Fig. 1. *Harvey and West's Double-Beat Valve.*

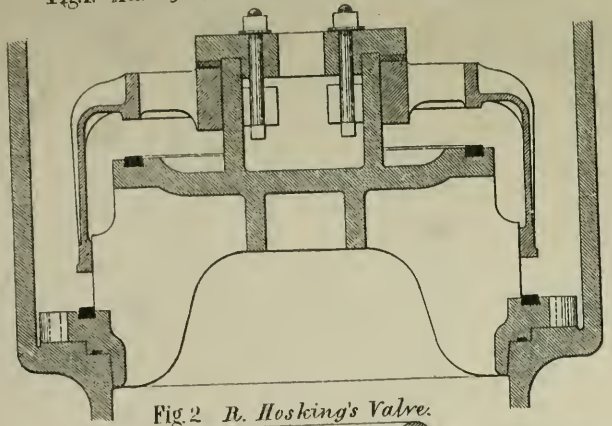
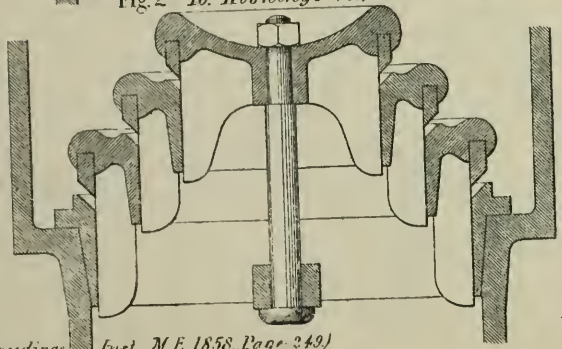


Fig. 2 *R. Hosking's Valve.*



(*Proceedings Inst M.E. 1858. Page 249*)

Scale 1/10th.

Fig. 3. *Jenkyns Valve.*

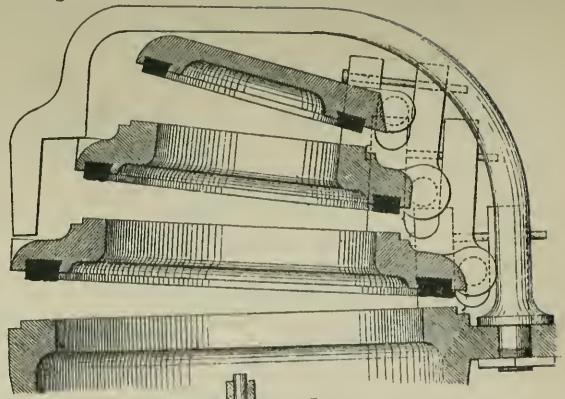


Fig. 4. *Simpson's Valve.*

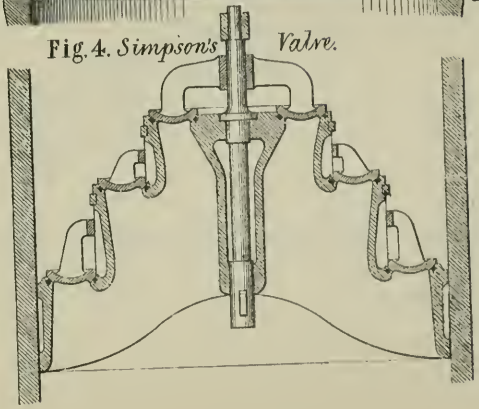


Plate 9.

PUMP VALVES.

Plate 62

Valve with Rings of Leather Clacks

Fig 5 *Vertical Section.*

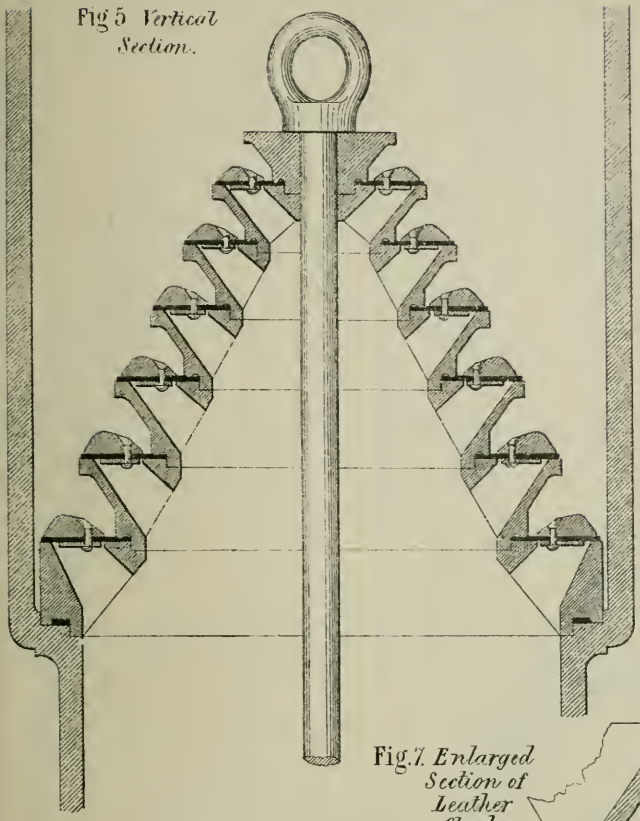
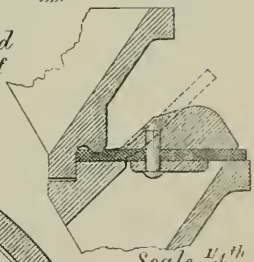
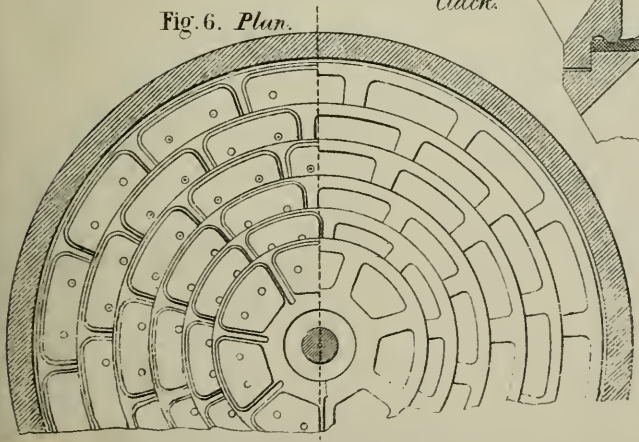


Fig. 7. *Enlarged Section of Leather Clack.*



Scale 1/4th

Fig. 6. *Plan.*



Scale 1/8th 0 1 2 3 4 5 6 7 8 9 10 20 Inches

(*Proceedings Inst. M.E. 1858. Page 249.*)

Valve with India-rubber Rings

Fig 8.
Vertical Section

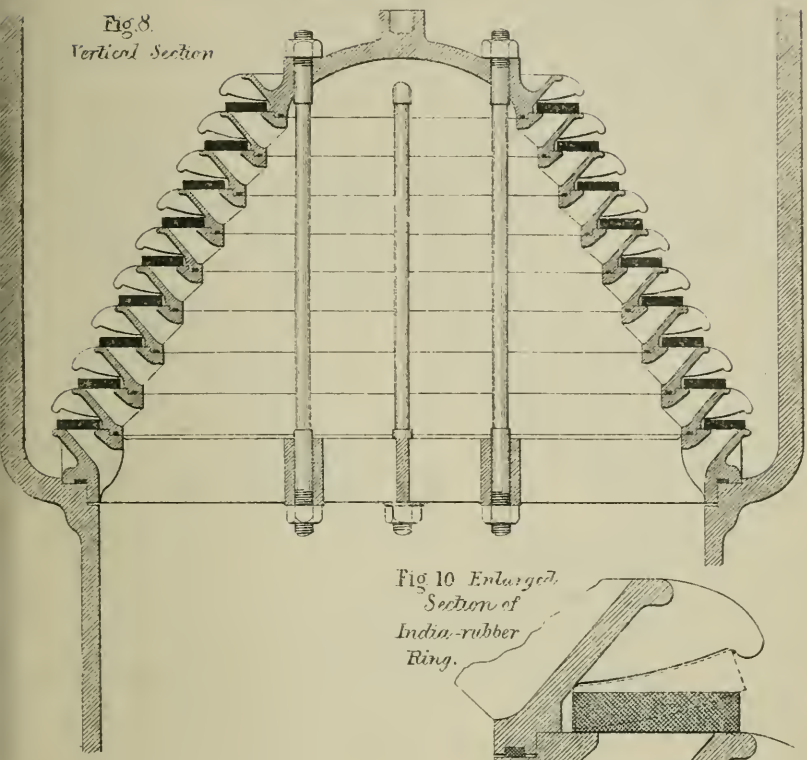
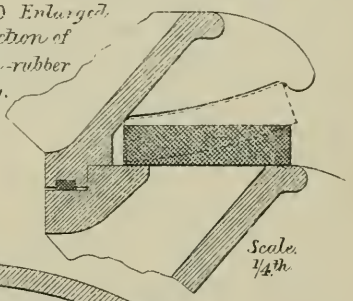
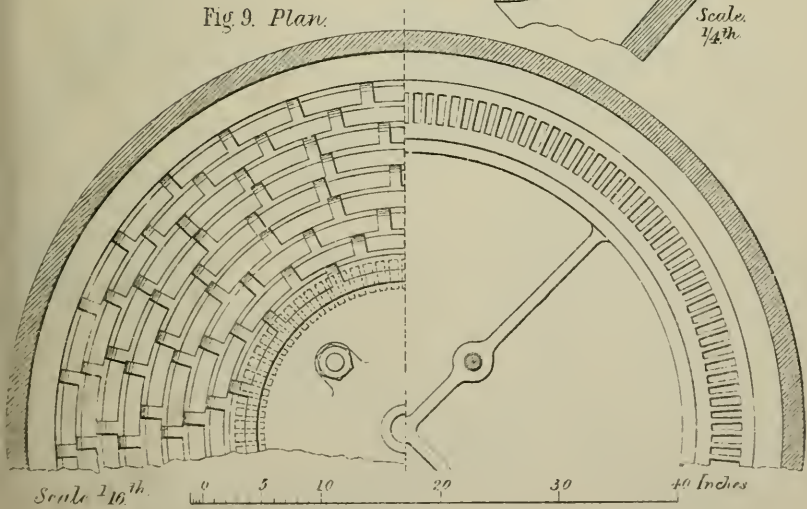


Fig 10 *Enlarged Section of India-rubber Ring.*



Scale 1/4th.

Fig 9. *Plan.*



Scale 1/16th

0 5 10 20 30 40 Inches

(*Proceedings Inst. M.E. 1858. Page 242.*

Valve with India-rubber Balls.

Fig. 11
Vertical Section.

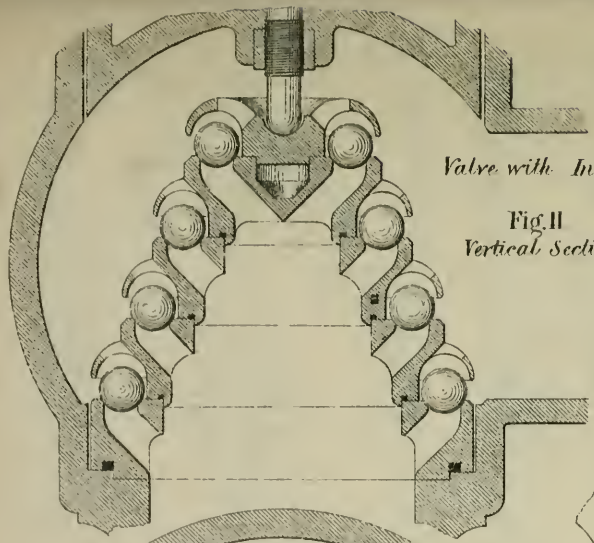
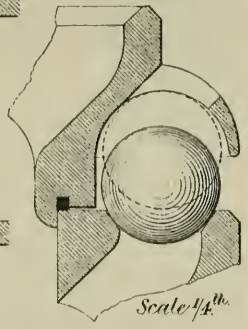
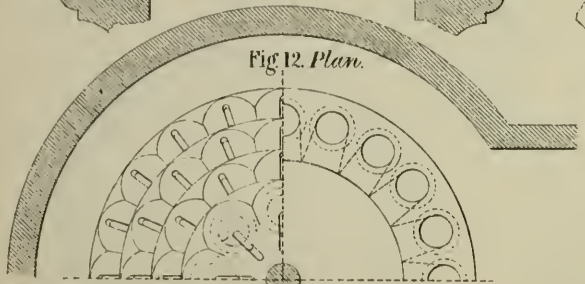


Fig. 13.
Enlarged Section, shewing India-rubber Ball.



Scale 1/4th.

Fig. 12. Plan.



(Proceedings Inst. M.E. 1852. Page 244)

Scale 1/10th.

Air Pump Bucket with India-rubber Rings.

Fig. 14. Vertical Section.

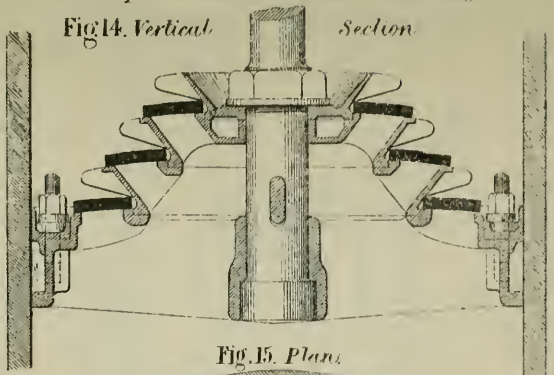
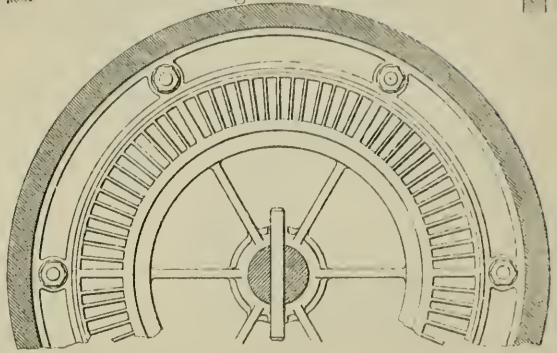


Fig. 15. Plan.



0 5 10 20 30 Inches

Plate 64.

Bucket with Rings of Leather Clacks.

Fig. 16. Vertical Section.

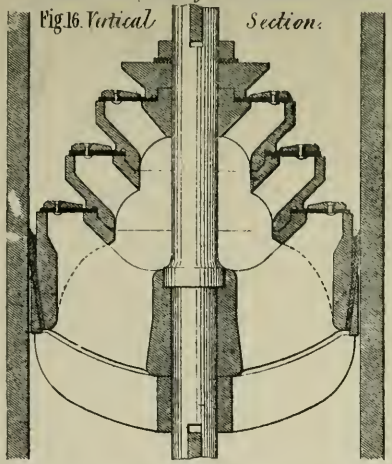
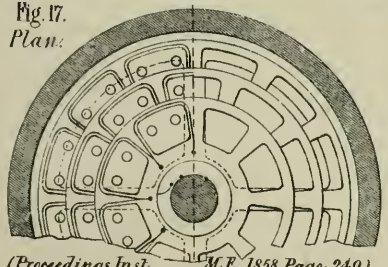


Fig. 17. Plan.



(Proceedings Inst. M.E. 1858. Page 249.)

Bucket with India-rubber Rings.

Fig. 18. Vertical Section.

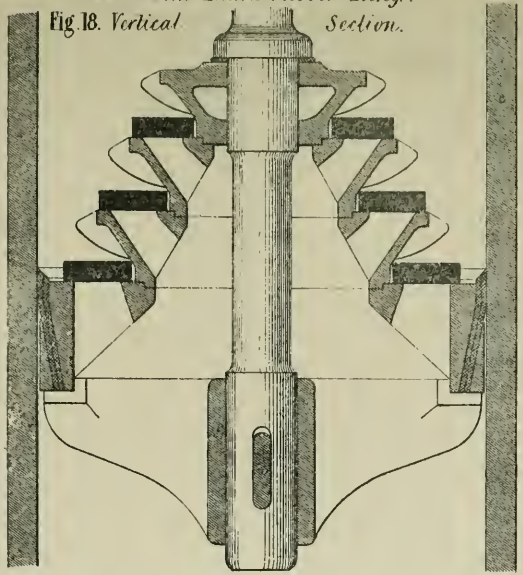
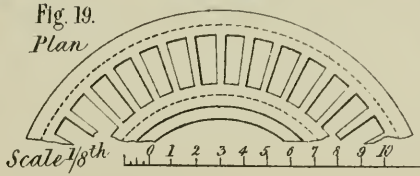


Fig. 19. Plan



Common Bucket

Fig. 20. Vertical Section.

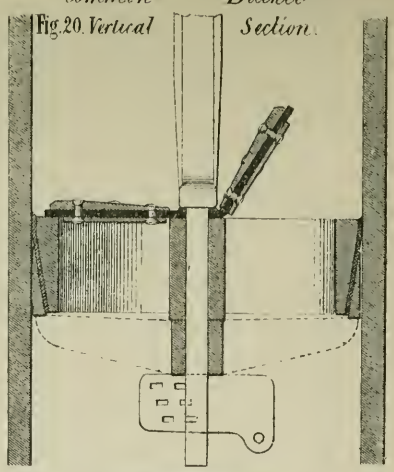


Fig. 21. Plan.

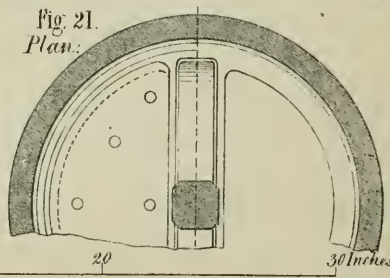


Plate 65.

Fig.1. *Plan of Engine Shed.*

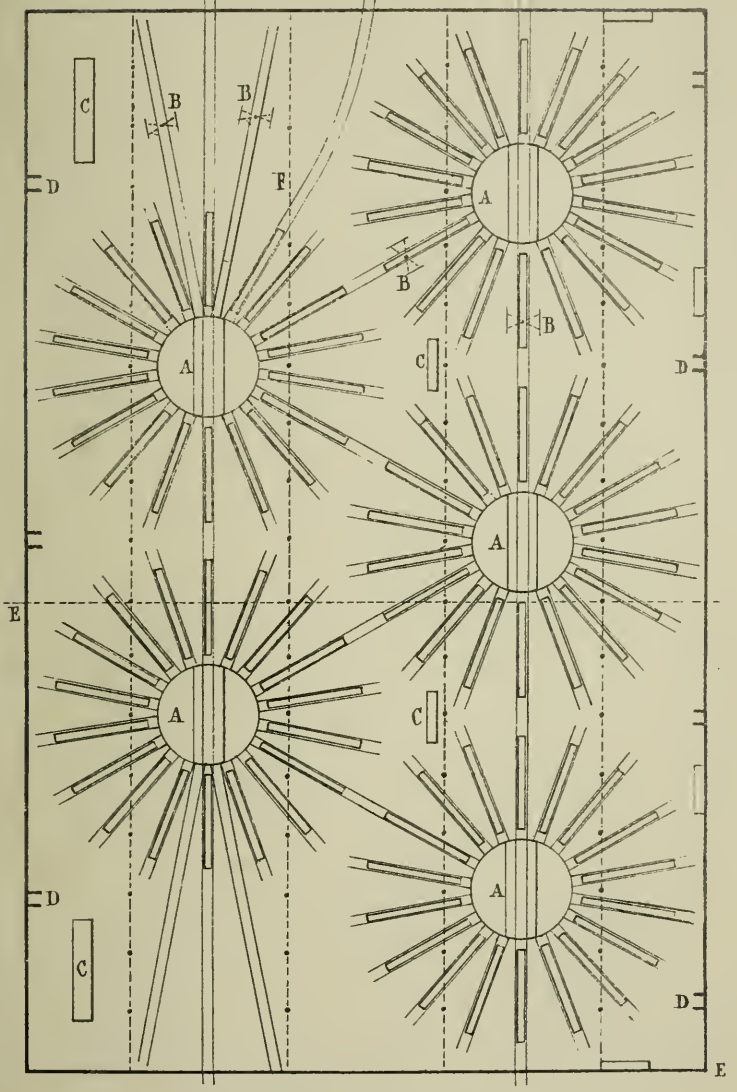
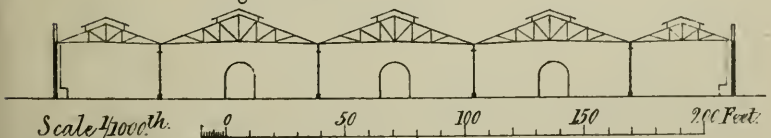


Fig.2. *Transverse Section.*



(Proceedings Inst. M.E. 1858. Page 256)

Fig. 3. *Transverse Section of Centre Roof.*

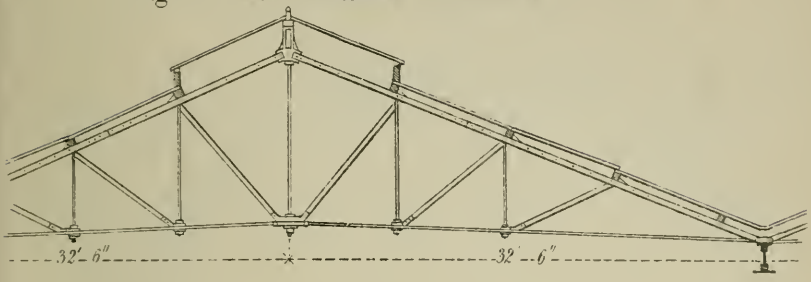


Fig. 4. *Elevation of Long Girder.*

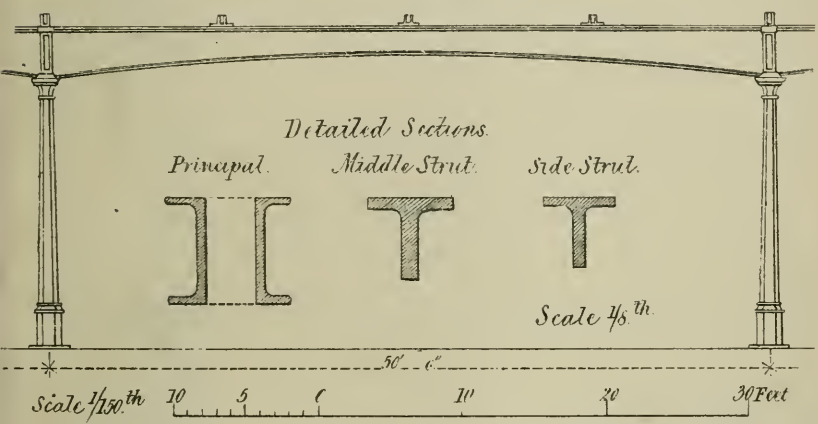
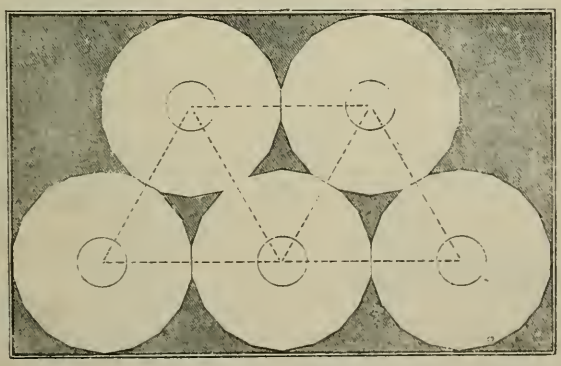


Fig. 5. *Diagram of General Plan.*



Scale 1/2000th

(*Proceedings Inst. M.E. 1858. Page 256.*)

Fig.6. *Plan of Engine Turntable.*

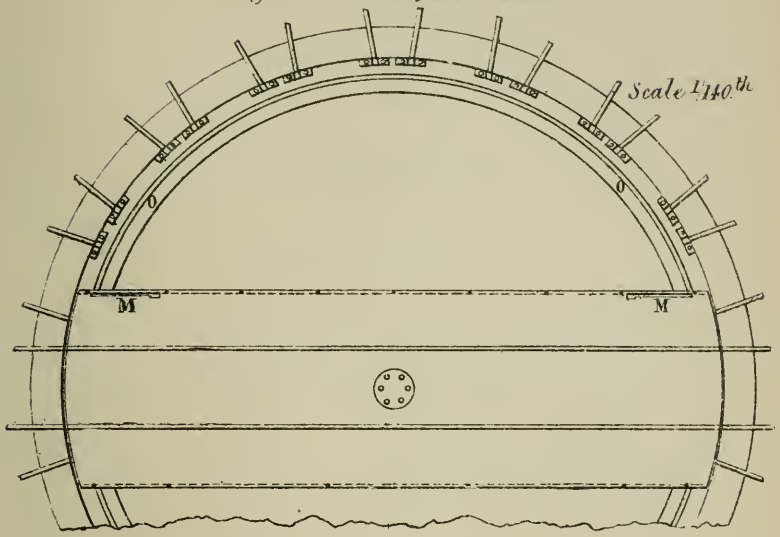


Fig.7. *Longitudinal Section*

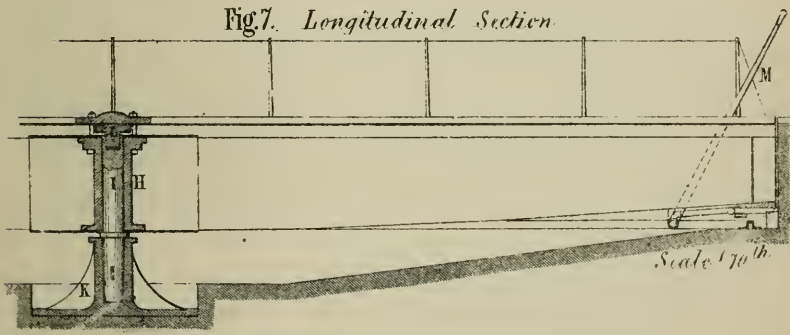


Fig.8 *Transverse Section at centre*

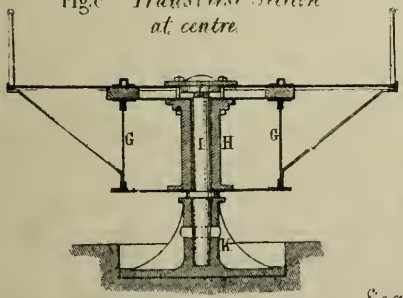
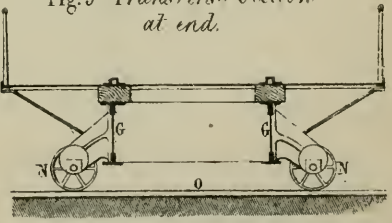


Fig.9 *Transverse Section at end.*



Scale 1/70th.

0 5 10 15 20 Feet.

(*Proceedings Inst M.E. 1858. Page 256*)

PROCEEDINGS.

November 3, 1858.

The General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 3rd November, 1858; Henry Maudslay, Esq., Vice-President, in the Chair.

The Minutes of the last Meeting, held in Newcastle-on-Tyne, were read and confirmed.

The Chairman announced that the President, Vice-Presidents, and five members of the Council in rotation, would go out of office in the ensuing year, according to the rules of the Institution; and that at the present Meeting the Council and Officers were to be nominated for the election at the Annual Meeting.

The following list of Members was adopted by the Meeting for the election at the Annual Meeting:—

PRESIDENT.

John Penn, ...	London.

VICE-PRESIDENTS.

(*Six of the number to be elected.*)

William G. Armstrong, .	Newcastle-on-Tyne.
Alexander B. Cochrane, .	Dudley.
James Fenton, . . .	Bradford.
Benjamin Fothergill, . .	Manchester.
Sampson Lloyd, . . .	Wednesbury.
Henry Maudslay, . . .	London.
John Ramsbottom, . .	Crewe.
Joseph Whitworth, . .	Manchester.

COUNCIL.

(Five of the number to be elected.)

Alexander Allan,	Perth.
William E. Carrett,	Leeds.
John E. Clift,	Birmingham.
Alexander B. Cochrane,	Dudley.
Edward Jones,	Wednesbury.
Nicholas Wood,	Hetton.
Henry Woodhouse,	Stafford.

The Chairman announced that the Ballot Lists had been opened by the Committee appointed for that purpose, and the following New Members were duly elected :—

MEMBERS.

Isaac Lowthian Bell,	Newcastle-on-Tyne.
Charles Cochrane,	Middlesborough.
Charles Cubitt,	London.
Edward Easton,	London.
Henry Allason Fletcher,	Whitehaven.
John Arthur Granet,	Paris.
George William Jaffrey,	Hartlepool.
Andrew Leslie,	Gateshead.
Thomas Meik,	Sunderland.
Peter Dale Nichol,	Calcutta.
Thomas Richardson,	Hartlepool.
Bergerius Sörensen,	Norway.
James Taylor,	Birkenhead.
Thomas John Taylor,	Newcastle-on-Tyne.
Hamilton Woods,	Newcastle-on-Tyne.

HONORARY MEMBERS.

Benjamin C. Lawton,	Newcastle-on-Tyne.
Thomas Waterhouse,	Sheffield.

Mr. B. Fothergill said that, as one of the deputation appointed from the Council to the Local Committee for the recent Meeting at Newcastle-on-Tyne, he had great pleasure in referring to the complete success of that meeting, and the great gratification experienced by the members attending it. These special provincial meetings formed a highly important and interesting portion of the proceedings of the Institution. The Newcastle Local Committee, to whom they were deeply indebted, had made great exertions to give the distant members a hearty welcome on the occasion of their visit, and to afford them an opportunity of seeing the engineering works in the neighbourhood thrown open for their inspection; and their friends joined cordially in the object and afforded every facility in their power for the purpose. The cordial reception given to them was highly gratifying; and much advantage was derived from the meeting by the members who attended, from the opportunity afforded them of seeing different operations and works new to them in the north of England.

A most appropriate and agreeable termination to the meeting was the visit of the members in the following day's excursion to the great engineering works in the neighbourhood: including the new Jarrow Docks, with their extensive shipping staiths and new coal-drop machinery; the Sunderland Bridge, an object of special interest, from its great span and bold design and the interesting works in progress for its reconstruction; and the Sunderland New Docks, with the extensive and ingenious hydraulic machinery for opening the gates and drawbridge and for working the large sluices for flushing the south outlet. The Hetton Colliery was then visited, the members travelling there in some of the original railway carriages on one of the earliest railways; and at Hetton they had a most cordial reception from Mr. Nicholas Wood, who afforded them every facility for seeing the works of the colliery and going down the pit, one of the largest in the north of England; and afterwards most hospitably entertained them at his residence, and forwarded them to meet the train for the south. Mr. Nicholas Wood had also kindly given an invitation to the members of the Institution to visit the Hetton Colliery whenever they had an opportunity of going into that neighbourhood.

Many members who had not attended the Newcastle meeting had much regretted their absence when they became acquainted with the nature and extent of the arrangements on that occasion, and the opportunities afforded for gaining valuable information. An important facility for attending the meeting had been very kindly afforded by the several Railway Companies, in permitting the members to go and return for a single fare, which was a valuable privilege as many of them came from a great distance; they might very likely in return have opportunities of aiding the railways in saving of fuel and other improvements in working.

He had great pleasure in announcing that it was now contemplated to hold a special meeting next summer at Leeds; and he trusted all the members would use their best endeavours to forward this desirable object, and strongly recommended them to attend on the occasion, when they would have opportunities of seeing the interesting machinery of the woollen and flax manufacture, and visiting the celebrated iron-works in that neighbourhood.

In reference to the visit of the members of the Institution to Hetton, he thought their thanks were specially due to Mr. Nicholas Wood; and he begged to propose "That the best thanks of this meeting be presented to Mr. Nicholas Wood, for his very kind and hospitable reception of the members of the Institution on the occasion of their recent visit to Hetton Colliery, and for the facilities afforded to them for viewing the works."

Mr. J. Fenton, as another member of the deputation from the Council for the Newcastle Meeting, had great pleasure in seconding the resolution, which was passed unanimously.

The following Paper, by Mr. Benjamin Fothergill, of Manchester, was then read :—

DESCRIPTION OF A SAFETY HOIST GOVERNOR.

In consequence of numerous accidents occurring in mills, warehouses, &c., where it is necessary to remove materials and goods from one floor or landing place to another by means of a hoist, the inventors of the safety apparatus forming the subject of the present paper, Messrs. Westhead and Baines, ascertained that in the majority of instances the accidents arose from other causes than the breakage of the suspending rope or chain; namely, fracture of the driving wheels, keys becoming loose, straps breaking, or the rope slipping on the pulley when the cage was overweighted, or the removal of the break when the engine was standing. This showed the necessity of introducing a simple safety apparatus, which should be brought into action whenever the velocity of the hoist in its descent attained a limit beyond which it would prove destructive to the machinery and expose the persons employed to imminent peril.

The principle of this invention consists in making the velocity of the hoist its own governor or regulator. This is accomplished by a pair of governor balls, similar to those ordinarily used in steam engines, placed on the top of the hoist, which are put in motion by a friction roller constantly pressing against the guide upon which the hoist works. Should the hoist ever attain a speed above that which it is originally regulated to travel at, the governor immediately releases a latch and sets free a number of serrated cams, which are thrown out against the guides and instantly arrest the descent of the hoist.

Figs. 1 and 2, Plate 69, are a side elevation and plan of the hoist with the safety apparatus; Fig. 3, Plate 70, is an elevation of the governor to a larger scale, and Fig. 4 shows one of the serrated break cams enlarged.

On the top of the hoist A is placed the governor B, receiving motion through the pulley C and bevil wheels from the friction roller D, which is held against the guide E by the spring F. GG are two shafts, one on each side of the hoist, on the ends of

which are fixed the four serrated break cams HH. The cams are kept free from contact with the guides E by the distance rods I attached to the disc K, which is capable of turning freely on the shaft of the pulley C. The latch L fits against a projecting snug on the face of the disc K and holds it stationary. When the hoist is in motion, it will work freely without hindrance from the break cams H, so long as the disc K is held stationary by the latch L; but the instant that the velocity of the hoist exceeds the limit at which it is intended to work, the governor balls flying apart bring the flange of the governor in contact with a projecting pin fixed in the tail of the latch L, Fig. 3, releasing the latch and setting free the cams H, which are thrown out against the guides by means of the springs M acting on the weighted levers N, and instantly stop the further descent of the hoist. The limit of velocity of the hoist is determined by adjusting the sizes of the friction roller D and pulley C.

There is also a further contrivance for ensuring safety in case of the winding rope breaking, consisting of a lever O, the inner end of which is carried under the tail of the latch L, Fig. 3, while the outer end is attached by a cord to the winding rope P. In the event of the rope breaking, the spring R acting on the lever O instantly releases the latch L and sets free the cams H, by which the descent of the hoist is arrested as before.

In this apparatus, the governor for limiting the speed of the hoist, and the contrivance connected with the winding rope as a safeguard against breakage, are entirely independent of each other in their action; while in either case, whether the speed at which the hoist travels be too great or the winding rope break, the same set of cams is instantly thrown into action to arrest the descent of the hoist. The retarding power of the cams is, in proportion to the weight of the hoist; for the heavier this is, the greater will be the force exerted by the cams in jamming themselves against the guides. The apparatus thus effectually preserves the machinery from injury in case of accident, and also affords protection and security to the persons employed on the hoist.

Mr. FOTHERGILL stated that the safety hoist had been in operation satisfactorily for several months with valuable results, and had already been the means of preventing serious accidents particularly from too great speed of descent of the hoist. In large warehouses, hoists were liable to accident from being overloaded, by too many men getting on the hoist thoughtlessly, or putting on too heavy a load of goods and several men getting on besides. This was one of the principal sources of accident, the balance weight being overpowered and the motion unduly accelerated, so that the hoist ran down much faster than intended; but with the contrivance now described the moment this occurred the governor balls flying out with the increase of velocity lifted up the latch and stopped the descent of the hoist instantly, by the powerful grip of the eccentric cams jamming themselves against the guides. The whole apparatus was simple and not liable to derangement; and not expensive, costing not more than £25 altogether for application to any hoist. In many warehouses two or more hoists were required, and at Messrs. Watts' large warehouse in Manchester two of these hoists had been in constant work for some time, which had been found quite satisfactory; and the plan would no doubt be advantageous for many different applications. By means of the small cord connected with the winding rope, if the rope broke, the spring to which the cord was attached instantly released the latch and set free the break cams, stopping the hoist directly; so that in either contingency of the breakage of the rope or the too rapid descent of the hoist, the same apparatus was instantly thrown into action, and completely prevented the further descent of the hoist.

Mr. W. SMITH had seen the safety hoist at work at Messrs. Watts' warehouse, and had tried experiments with it to ascertain the certainty and efficiency of its action; and he considered that if the strength of the parts were amply sufficient to stand the strain, the apparatus would prove thoroughly efficient and satisfactory. He had tried it with the guides greased, and put it to the severest test practicable with heavy loads, and found it quite efficient; and he thought that if the rotation of the governor by friction could be always ensured, the apparatus would answer well, but it must be secure against any slip of the friction roller taking place. The

height to which these hoists were now carried in warehouses was very great, and from the increased danger of accident he thought this safety apparatus should be added to all; it was of great value for preventing accident not only from breakage of the rope but in case of the key coming out of the lifting pulley or the break of the pulley not acting, and these were more frequent causes of accident than the rope breaking. For railway hoists also, where the weight moved was very great, the apparatus might no doubt be applied with much advantage.

In the construction of the hoist gear he thought that, instead of trusting to the adhesion of the friction roller for driving the governor, the use of a toothed wheel and rack with shallow teeth well rounded would be preferable, as more secure against slipping. It also occurred to him to suggest that the four ball governor would be more applicable than the ordinary governor, as the whole operation was so momentary; and since the velocity of descent would increase rapidly when the hoist had begun to fall, it was desirable to get as instantaneous an action as possible to prevent its falling beyond a very short distance.

The CHAIRMAN remarked that the four ball governor might be placed upon the horizontal shaft and driven direct by the friction roller, thus avoiding the intermediate friction belt, and would then be more direct in its action.

Mr. C. W. SIEMENS thought it an excellent idea to arrest the motion of a falling body by the action of a governor, and its application to a hoist would give an important additional security against accident. With regard to the mode of action of the cams, he considered they were put in action entirely by the spiral springs, and that the weights upon the cam levers should be dispensed with; as the whole apparatus fell together, both the weights and the hoist would be accelerated equally, without any tendency for the weights on the levers to change their relative position unless some resistance of friction retarded the motion of the hoist at starting, so as to allow the small weights to overrun the rest of the apparatus to a sufficient extent for throwing the cams into action.

Mr. FOTHERGILL said he had recommended the application of the spiral springs in order to make the break levers more prompt and

certain in action; as there could be no doubt that the whole hoist would be acted upon by gravity equally with the small weights. In reference to the mode of communicating motion to the governor, the apparatus had at present been constructed with a plain friction roller running against the guide, as shown in the drawings; but a rack slightly indented would certainly be more perfect, though involving the additional expense of the rack extending the entire height of 60 or 80 feet in several instances. The hoist was equally safe with heavy and with light loads, for the greater the load the greater was the holding power of the cams in consequence of their eccentric form; and he thought it was very desirable that the apparatus should be added to all hoists, as an effectual means of preventing the accidents to which they were now liable.

Mr. Sampson Lloyd thought the safety apparatus might be applied with great advantage to mines, where the number of cases for its application would be far greater than in warehouses; the importance of an efficient safety apparatus was much greater in mines, from the increased depth and the greater risks that were incurred. The application of the plan would of course require cages and guides in the shafts, but these were now being generally adopted on account of their advantages in working.

Mr. Fothergill said the plan would be quite applicable to mines; and he would be happy at a future meeting to give a description and model of its application to railway hoists, which was being carried out.

The Chairman proposed a vote of thanks to Mr. Fothergill for his paper, which was passed.

The following Paper, by Mr. Joseph Tomlinson, of Cardiff, was then read:—

ON THE BURNING OF WELSH STEAM COAL IN LOCOMOTIVE ENGINES.

The use of coal in locomotive engines having become almost the rule, the writer offers the following results of a series of trials he has made with the Steam Coals of South Wales in Locomotive Engines upon the Taff Vale Railway, in comparison with the best descriptions of coke to be had in the same district; as there has hitherto been a difficulty in the use of that description of coal for such a purpose almost amounting to prohibition, from the fact that in all previous trials a failure has resulted from the burning of the firebars. This failure of the Welsh steam coal in locomotive engines has been hitherto attributed to the firebars becoming clinkered over; but the results of the trials described in the following paper appear to show that the failure has arisen from an entirely different cause, and one that can be completely obviated.

The writer was originally driven to the use of coal alone for carrying on the traffic of the Taff Vale Railway in January last, in consequence of the continued strike of the colliers in the Rhondda Valley where the coking coal is obtained. Previous to that time little or no coal had been used in the locomotives, owing to the good quality and low price of the coke; and from the idea that coal could not economically compete with coke for the heavy work of this line, and also from the known difficulties to be overcome in its employment. The transition from coke to coal being sudden and unprepared for, it became necessary to watch the matter closely, so as to determine which of the various descriptions of coal would answer the purpose best, and to arrange its treatment; more especially as at the outset, from the various qualities of coal that had to be used, the firebars were continually being burnt out, and seldom could be made to last two days without passing through the hands of a smith to be separated and straightened; even then several bars a day were totally destroyed in each engine, some engines having had two entire new sets a day to run

100 miles. After careful consideration of the subject it was decided to use only one description of coal; the preference was then given to the steam coal over the bituminous, as being more pure in its composition and smokeless; and after attentive observation and trials the Aberdare Four Feet Vein coal was chosen. With this coal it was found that the least damage was done to the firebars, and the best result obtained by working the engine with a very thin fire, say not exceeding 9 inches with a moderate load, and slightly thicker as the load increased, not however exceeding 15 inches in any case. In working with a light train or down hill with a loaded train, it was found advantageous to keep even a more shallow fire than 9 inches; for the blast being very light, (as little or no traction is required down hill on this railway), the supply of steam could not be kept up unless the air were admitted with little difficulty; it is however necessary to be prepared in case of being stopped, and therefore a bright fire was a desideratum which could not be obtained unless it were kept thin.

The injury to the firebars was however still a great item, notwithstanding all the care that could be bestowed on them; for it is difficult to get a number of men to attend implicitly to rules which give them more trouble than they have previously been accustomed to. The writer was therefore induced to try an experiment by covering up the entire surface of the bars with small pieces of firebrick, not exceeding 3 inches cube, and putting the fire on them, so as to prevent the direct action of the fire on the iron of the bars; and it was found that from the clean nature of the coal no bad result took place in the generation of steam, while the bars now received little or no injury. Figs. 1 and 2, Plate 71, are a longitudinal and transverse section of a locomotive firebox, showing the layer of broken pieces of firebrick on the bars. This plan has consequently been generally adopted, but with the partial substitution of clinker from stationary engines instead of firebrick alone. It has completely obviated the difficulty of the bars being burnt, and a set of bars will now last on an average four months, running about 100 miles a day. It is also attended with a beneficial result; for the small coal, instead of passing directly into the ashpan unconsumed, adheres partially to the red-hot brick and clinker, and is consumed; and notwithstanding that the Welsh steam coal falls

readily to small, and has little if any binding property, the engines can run 100 miles without cleaning out the ashpan. Another description of coal containing a larger percentage of ash has also been tried for getting up steam and making the first fire to start with, which clinkering slightly on the bars most effectually protected them from burning: the use of this coal was however limited to 5 cwt. per day for each engine.

To place the engine more out of the control of the men, the plan was adopted which has been in use on other engines, of perforating the shield of the firedoor and drilling five or six 2 inch holes in the door itself, as shown in Figs. 4 and 5, so as to admit a little air above the fire; this was found useful not only in assisting combustion but also in preventing the blast from lifting the small particles of coal and thereby choking the tubes.

Having so far succeeded in efficiently working the traffic entirely with coal, and finding the engines were working the trains with a smaller weight of fuel than they had previously done, the writer was disinclined to return to coke without good reason, after the experience he had had. A series of experiments was therefore made to test the commercial value of each description of fuel. The particulars of these experiments are given in Tables I to VII (appended). Tables I and II show the results of experiments made with an engine working the regular mineral trains, with Aberdare Four Feet Coal and Rhondda Valley Best Coke: and Tables III and IV give the experiments with the same coal and coke with a special train of 35 loaded coal wagons weighing 269 tons, run at the regular speeds of the ordinary trains of about 11½ miles per hour. Table V gives experiments with various fuels with a special train of 40 loaded coal waggons weighing 314 tons, run at a speed of 20 miles per hour up the hill and 12 miles down; (12 miles per hour being the limit down hill with loaded trains). Tables VI and VII show the results of experiments with Bastard Steam Coal and Aberdare Nine Feet Coal: the former of these has a larger percentage of ash and more bituminous property, the only objection to its use being the smoke; it does not burn the bars and is fully as economical as the pure steam coal.

The whole series of experiments were made with the same engine and by the same engineman. The engine is of the following dimensions: cylinders 16 inches diameter and 24 inches stroke; six wheels coupled, 4 feet 6 inches diameter; firebox 3 feet 6 inches square by 4 feet 10 inches high; 156 tubes, 13 feet 3 inches long by 2 inches diameter, and No. 11 to No. 14 wire gauge thickness; safety valves loaded to a pressure of 110 lbs. per square inch. A section of the Taff Vale Railway is given in Fig. 6, Plate 71, showing the several gradients along the line, the mean gradient being 1 in 309.

The following Table gives the general results of the whole of the experiments, showing the quantity of fuel consumed per ton per mile, the quantity of water evaporated per lb. of fuel, and the average speed of the train during running:—

Description of Fuel.		Fuel consumed per ton per mile.	Water evaporated per lb. of fuel.	Speed in running Miles per hour.
		lb.	lbs.	miles.
Coal—Aberdare Four Feet Vein ...	Table I	·127	7·63	11·5
Coke—Rhondda Valley Best Coke	II	·172	7·62	11·5
Coal—Aberdare Four Feet Vein	III	·130	8·37	11·5
Coke—Rhondda Valley Best Coke	IV	·124	8·34	11·3
Coke—Rhondda Valley Best Coke	V	·136	7·54	16·8
Coal—Aberdare Four Feet Vein, lump ...	V	·133	7·73	16·5
Coal—Do., half lump and half small ...	V	·153	7·11	14·8
Coal—Rhondda Valley Bastard Steam Coal	VI	·110	8·63	11·5
Coal—Aberdare Nine Feet Vein	VII.	·112	8·15	11·5

The results in the consumption of fuel showing in all cases slightly in favour of the coal, they may fairly be considered equal; and as the abuse of the engine when burning coal is more easily detected than when using coke, this forms a further advantage in favour of coal. The preference may also be given to coal over coke for the freedom in generating steam, which will allow the blast pipe to be of larger dimensions than when burning coke. This has been clearly shown, as the engines are now maintaining steam at 100 to 110 lbs. per square inch with coal, with the same sized blast pipes as were used

previously for 80 lbs. with coke; and the firebars have also been placed closer together, the air spaces being reduced from 1 inch to $\frac{5}{8}$ inch. Hence the writer thinks it may be concluded that the Welsh smokeless coal may be economically used in substitution for coke; and that where failures have taken place previously, they are to be attributed to the very great heating power of the coal; and that the difficulty with firebars has resulted not from clinker, but from the absence of a proper protection for the iron of the bars, so that with heavy firing the heat has struck downwards and fused the bars themselves.

Nearly all the engines on the Taff Vale Railway are now burning Welsh steam coal entirely; they take with each train a load of 80 empty waggons averaging $3\frac{1}{4}$ tons each or 260 tons total, up an average rising gradient of 1 in 309, at from 13 to 14 miles per hour without any inconvenience.

The composition of the Aberdare Four Feet Vein, the coal now in use in these engines, is

Carbon	90·25
Hydrogen	4·12
Oxygen	2·25
Nitrogen, &c.	2·13
Ash	1·25
	100·00

It is therefore practically coke, and requires only proper treatment for substitution in the place of coke. Another great advantage in the use of this coal over all others in locomotive engines is its almost entire freedom from smoke, thus rendering any plan of smoke burning unnecessary, not even a steam jet being required when the engine is standing.

The advantage of slow speed is so distinctly shown in the results obtained that the writer considers this point is worthy of more attention than it usually receives on railways; for a slow speed not only economises the quantity of fuel consumed by diminishing the resistance of the train, but also increases the evaporative duty obtained from it.

TABLE I.

Experiments with Welsh Steam Coal.

Aberdare Four Feet Vein.

Regular Mineral Trains.

Date of Experiment.	Distance run.	Speed in running. Miles per hour.	Pressure of Steam per sq. inch.	Weight of Train.			Coal consumed.			Water evaporated.		Remarks.
				Up.	Down.	Mean.	Total.	Per mile.	Per ton per mile.	Total.	Per lb. of coal.	
1858.	Miles.	Miles.	lbs.	Tons.	Tons.	Tons.	lbs.	lbs.	lb.	lbs.	lbs.	
May 4.	88	11·5	110	150·6	424·5	287·6	3752	42·64	·148	26312	7·01	Weather fine.
May 5.	88	11·5	110	124·7	520·7	322·7	2968	33·73	·105	22126	7·46	Do.
May 6.	88	11·5	110	79·9	531·8	305·8	2744	31·18	·102	23472	8·55	Do.
May 8.	90	11·5	110	113·3	342·7	228·0	3640	40·44	·177	25116	6·90	Do.
May 11.	100	11·5	110	242·9	632·4	437·6	5320	53·20	·122	41412	7·78	Do.
May 12.	100	11·5	110	229·8	590·5	410·2	4872	48·72	·119	39319	8·07	Do.
Average	92·3	11·5	...	156·9	507·1	332·0	3883	42·07	·127	29626	7·63	

TABLE II.

Experiments with Welsh Coke.

Rhondda Valley Best Coke.

Regular Mineral Trains.

Date of Experiment.	Distance run.	Speed in running. Miles per hour.	Pressure of Steam per sq. inch.	Weight of Train.			Coke consumed.			Water evaporated.		Remarks.
				Up.	Down.	Mean.	Total.	Per mile.	Per ton per mile.	Total.	Per lb. of coke.	
1858.	Miles.	Miles.	lbs.	Tons.	Tons.	Tons.	lbs.	lbs.	lb.	lbs.	lbs.	
May 27.	100	11·5	100	255·9	183·6	219·7	5880	58·80	·268	40515	6·89	Slight rain & fair.
May 28.	100	11·5	85	240·9	257·3	249·1	4928	49·28	·198	36179	7·34	Fine and dry.
May 29.	88	11·5	95	114·6	701·0	407·8	3528	40·09	·098	26312	7·46	Fine.
June 1.	88	11·5	82	92·4	281·8	187·1	2968	33·73	·180	27758	9·35	Fine.
June 2.	90	11·5	90	184·3	369·9	277·1	4088	45·42	·164	31096	7·61	Rain.
June 3.	92	11·5	100	237·2	410·7	324·0	5208	56·61	·175	40963	7·87	Rain and fair.
Average	93	11·5	...	187·5	367·4	277·5	4433	47·67	·172	33804	7·62	

TABLE III.

Experiments with Welsh Steam Coal.

Aberdare Four Feet Vein.

Special Trains of 35 loaded coal wagons.

Date of Experiment.	Distance run.	Speed in running. Miles per hour.	Pressure of Steam per sq. inch.	Weight of Train.	Coal consumed.			Water evaporated.		Remarks.
					Total.	Per mile.	Per ton per mile.	Total.	Per lb. of coal.	
1858.	Miles.	Miles.	lbs.	Tons.	lbs.	lbs.	lb.	lbs.	lbs.	
July 8.	100	11·6	110	269	3752	37·52	·139	29601	7·89	Rain 1st trip. Fair 2nd trip.
July 9.	101	11·2	110	269	3532	34·97	·130	30050	8·51	Fine and dry.
July 10.	101	11·8	110	269	3612	35·76	·133	30349	8·40	Fine and dry.
July 12.	100	11·5	110	269	3192	31·92	·119	27957	8·76	Fine and dry.
Average	100·5	11·5	...	269	3522	35·04	·130	29489	8·37	

TABLE IV.

Experiments with Welsh Coke.

Rhondda Valley Best Coke.

Special Trains of 35 loaded coal wagons.

Date of Experiment.	Distance run.	Speed in running. Miles per hour.	Pressure of Steam per sq. inch.	Weight of Train.	Coke consumed.			Water evaporated.		Remarks.
					Total.	Per mile.	Per ton per mile.	Total.	Per lb. of coke.	
1858.	Miles.	Miles.	lbs.	Tons.	lbs.	lbs.	lb.	lbs.	lbs.	
July 14.	100	11·2	110	269	3536	35·36	·131	26910	7·61	Fine and dry.
July 15.	100	11·3	110	269	3234	32·34	·120	27658	8·55	Fine and dry.
July 16.	100	11·1	110	269	3256	32·56	·121	27658	8·49	Fine and dry.
July 17.	100	11·5	110	269	3328	33·28	·124	29153	8·76*	Fine and dry.
Average	100	11·3	...	269	3338	33·38	·124	27845	8·34	

* Blow-off cock opened during trip in consequence of priming.

TABLE V.

Experiments with various Fuels.

Special Trains of 40 loaded coal wagons,
run at 20 miles per hour up hill and 12 miles down.

Date of Experiment.	Description of Fuel.	Distance run.	Speed in running. Miles per hour.	Pressure of Steam per sq. in.	Weight of Train.	Fuel consumed.			Water evaporated.		Remarks.
						Total.	Per mile.	Per ton per mile.	Total.	Per lb. of fuel.	
1858.		Miles.	Miles.	lbs.	Tons.	lbs.	lbs.	lb.	lbs.	lbs.	
July 19.	*Coke—Rhondda Valley Best Coke.*	100	16·8	110	314·2	4284	42·84	·136	32292	7·54	Fine and dry.
July 20.	Coal { Aberdare Four Feet Vein, lump. }	100	16·5	110	314·2	4180	41·80	·133	32292	7·73	{ Slippery 1st trip. Fair 2nd trip.
July 21.	Coal { Aberdare Four Feet Vein, half lump and half small. }	100	14·8*	{ 110 / 80 }	314·2	4816	48·16	·153	34236	7·11†	Fine and dry.
July 22.	Coal—Newcastle Coal, half small.	100	15·1*	110	314·2	6020	60·20	·192	31694	5·26	Fine and dry.

* Stopped on road to clean out smokebox: speed of 20 miles per hour could not be maintained owing to heating of smokebox.

† Water lost by priming say 2542 lbs., making the water evaporated 6·58 lbs. per lb. of coal.

TABLE VI.

Experiments with Welsh Steam Coal.

Rhondda Valley Bastard Steam Coal.

Regular Mineral Trains.

Date of Experiment.	Distance run.	Speed in running. Miles per hour.	Pressure of Steam per sq. inch.	Weight of Train.			Coal consumed.			Water evaporated.		Remarks.
				Up.	Down.	Mean.	Total.	Per mile.	Per ton per mile.	Total.	Per lb. of coal.	
1858.	Miles.	Miles.	lbs.	Tons.	Tons.	Tons.	lbs.	lbs.	lb.	lbs.	lbs.	
June 5.	100	11·5	95	195·9	489·5	342·7	4256	42·56	·124	33040	7·76	Fine and dry.
June 7.	100	11·5	78	208·4	414·1	311·2	3920	39·20	·126	34385	8·78	Fine and dry.
June 8.	90	11·5	86	104·0	631·8	367·9	3360	37·33	·101	30498	9·08	Fine and dry.
June 10.	90	11·5	85	159·5	551·1	355·3	3080	34·22	·096	26163	8·49	Fine and dry.
June 11.	90	11·5	80	203·7	686·1	444·9	4004	44·49	·100	34983	8·74	Fine and dry.
June 12.	90	11·5	92	216·7	465·1	340·9	3528	39·20	·115	31993	9·07	Fine and dry.
Average	93·3	11·5	...	181·4	539·6	360·5	3691	39·55	·110	31844	8·63	

TABLE VII.

Experiments with Welsh Steam Coal.

Aberdare Nine Feet Vein.

Regular Mineral Trains.

Date of Experiment.	Distance run.	Speed in running. Miles per hour.	Pressure of Steam per sq. inch.	Weight of Train.			Coal Consumed.			Water evaporated.		Remarks.
				Up.	Down.	Mean.	Total.	Per mile.	Per ton per mile.	Total.	Per lb. of coal.	
1858.	Miles.	Miles.	lbs.	Tons.	Tons.	Tons.	lbs.	lbs.	lb.	lbs.	lbs.	
August 4.	100	11·5	110	212·7	612·0	412·3	4564	45·64	·111	36478	7·99	Wet and slippery.
August 5.	100	11·5	110	228·2	381·4	304·8	4382	43·82	·144	37076	8·46	Fine and dry.
August 6.	90	11·5	110	168·6	555·4	362·0	3878	43·09	·119	30050	7·75	Fine and dry.
August 7.	90	11·5	110	180·4	898·9	539·7	4388	48·76	·090	36628	8·35	Fine and dry.
Average	95	11·5	...	197·5	611·9	404·7	4303	45·29	·112	35058	8·15	

Mr. Tomlinson showed specimens of the various descriptions of coal, and of the firebrick before and after using it in the engine fire; and explained that the firebrick was merely broken up into small pieces of about 3 inches cube, and thrown in roughly with a shovel in a single layer over the grate, so as to cover the firebars: it was found to last a long time, and in one special trial that he had made to ascertain its durability the fire was not dropped for six days, the engine running continuously 100 miles per day, and at the end of that time the firebrick still remained as an efficient protection for the grate bars.

The Chairman enquired what clay was used for the firebrick.

Mr. Tomlinson replied that it was the local fireclay from the Rhondda Valley, which answered well. The thickness of the fire was an important point: it might be 9 or 10 inches thick at the sides, where the absorbing surfaces of the firebox kept down the temperature; but should be as thin as possible in the centre, so that the bars could just be seen through it, for the bars would go down in the centre in spite of all precautions unless the fire was kept very thin, on account of the intense heat.

In the table of experiments the injurious effect of increased speed was remarkably shown, not only in increased consumption of fuel, but also in diminished evaporative duty of the fuel, which was reduced about 10 per cent. by an increase of speed of $5\frac{1}{2}$ miles per hour or about 50 per cent.

In the trial that he had made of Newcastle coal, the coal used was some that had been tried in steam boats in comparison with Welsh coal, and he had made a trial of a small quantity in a locomotive; it was half small coal, and therefore would not serve for comparison with the large Welsh coal used in the experiments: but the trial showed that the bituminous Newcastle coal demanded very different circumstances for its economical consumption, requiring a much greater supply of air; it consequently received imperfect treatment in ordinary locomotive fireboxes, where no provision was made for an extra supply of air beyond that admitted through the grate; so that the evaporative duty obtained in the trial was only $5\frac{1}{4}$ lbs. of water per lb. of fuel.

The results of the trials in consumption per ton per mile were not always thoroughly reliable as a means of comparison, on account of

the great fluctuation in the weight of trains down, some being as much as 700 or 800 tons down hill, which would materially affect the result; the fall was nearly uniform from one end of the line to the other, amounting to 409 feet in 24 miles, or an average gradient of 1 in 309. The trains wanted scarcely any power down hill, and required the break to regulate the speed, which was not allowed to exceed 12 miles per hour on account of the number of heavy trains upon the line.

Mr. J. E. Clift asked what was the comparative cost of the different kinds of fuel used in the experiments, as that was an important point in the question of the use of coal in place of coke.

Mr. Tomlinson replied that the coke cost 12*s.* 6*d.* per ton and the coal 6*s.* 8*d.* per ton in the wagons upon the railway; so that the cost of fuel when coal was used was little more than half of that with coke, as the consumption was about the same in quantity to do the same work.

Mr. R. Laybourn said he had made some trials of burning Welsh coal in locomotives on the Monmouthshire Railway about 18 months ago, with coal from Nixon's Deep Duffryn seam, the same seam of coal as the Aberdare Four Feet Vein, but found the bars came down in the same way as had been described: this was however obviated by using inferior coke for lighting the fire, which formed a portion of clinker over the bars that served to protect them; by this means he succeeded in using the coal. The difference in price between coal and coke was considerably less in that instance, the Nixon's Deep Duffryn coal costing 11*s.* 6*d.* per ton on account of having to be conveyed over two or three different railways; while the best coke cost 15*s.* per ton, and inferior coke 12*s.* to 13*s.* per ton.

He had been driven to investigate the subject of coal-burning in locomotives about two years ago by the difficulty experienced in the supply of coke, and made a series of experiments, which led him to the adoption of a considerable proportion of coal mixed with the coke for the locomotives on the Monmouthshire Railways. In the half year ending December 1855, and previously, coke alone had been used, at an average rate in that half year of 40 lbs. per mile for all the trains, passenger and goods, costing 3·12*d.* per mile of the trains for fuel. In the following half year to June 1856 a quantity of coal was mixed

with the coke; and in the next half year to December 1856 this was increased to an average of 22·73 lbs. of coal per mile and 17·85 lbs. of coke, making a total consumption of 40·58 lbs. per mile, at a cost of 2·56*d.* per mile of the trains for fuel. The proportion of coal was then further increased, and the results were—

In the half year ending	Coal.	Coke.	Total Consumption.	Cost of Fuel.
June 1857	39·25 lbs.	5·60 lbs.	44·85 lbs. per mile	2·09*d.* per mile.
Dec. 1857	39·71	5·20	44·91 —	2·13 —
June 1858	34·15	7·21	41·36 —	2·10 —

The coal used was steam coal of a semi-anthracite and semi-bituminous quality, obtained from the Monmouthshire valleys on the eastern side of the Welsh coal district; it was not so anthracite as the Welsh steam coal which was found at some distance westward from the district of the Monmouthshire Railways, in the Aberdare and Swansea valleys.

The Chairman asked whether he had tried covering the grate with firebrick.

Mr. R. Laybourn said he had not tried firebrick, but by getting up the fires with inferior coke a clinker was formed over the grate, which was found to answer the purpose of protecting the bars; the Monmouthshire coal was not so liable to burn the bars as the Welsh coal, but it was still requisite to use it with a thin fire.

Mr. J. Fenton enquired whether the weight of the trains given in the particulars of the experiments included the engine and tender, as that was important for any comparison with the results obtained on other railways.

Mr. Tomlinson replied that the weights given were those of the trains alone, independent of the engine and tender, which would add about 45 tons, the engine being about 29 tons weight and the tender 16 tons.

Mr B. Fothergill had been engaged recently in an extensive series of experiments on the comparative value of coal and coke as fuel for locomotive engines: and the results of his observations led him to agree entirely with the statements in the paper, as to the efficiency of coal for locomotives in place of coke; and that the quantity of coal required was not greater to do the same work, if suitable

provision was made for its proper combustion. His experiments had been made with the partially bituminous coal of Lancashire and Yorkshire; and he had also made one trial with the Welsh smokeless coal in a locomotive engine, but it was impracticable to complete that trial in consequence of the firebars melting down upon the trip so as to stop the engine after having run only a short distance. It was not from defect of the coal that this stoppage of the trial took place, but entirely from the melting of the firebars; and it was evident that without some provision for protecting the bars from melting, the Welsh smokeless coal could not be employed in locomotives.

The question of coal-burning in locomotive engines was a highly important one, and called for the careful attention of railway companies, as to the saving to be effected in their working expenses by the substitution of coal for coke. In two trials he had made, the cost of fuel for taking the same train over the same distance of 96 miles was found to be

with Coke at 11*s.* 6*d.* per ton . . .	22*s.* 3*d.*
with Coal at 5*s.* 3*d.* per ton . . .	9*s.* 5*d.*

showing a saving of 57 per cent. in the cost of fuel consumed when coal was used. He should be happy on a future occasion to bring before the Institution the particulars and results of the trials; and was glad to say he had come unreservedly to the conclusion that there was no necessity for noxious volumes of smoke being discharged from locomotive engines with the use of coal, but they might always be made to burn their smoke satisfactorily. There was not only a great saving in cost of fuel attending the use of coal, but a great convenience to the drivers in keeping up the steam better than with coke; and those accustomed to it would rather run a coal-burning engine, if the smoke were consumed, than a coke engine.

There was another point of great importance to be noticed in reference to the subject,—the relative durability of the boiler tubes and firebox with coal and with coke; and after the practicability of using coal with great economy in cost of fuel had been established, this became a serious question in deciding whether to go on making coal-burning engines instead of coke engines. It had been feared at first that there would be a loss from more rapid destruction of the

brass tubes and copper firebox with coal than with coke; and he had been recently engaged in an investigation of the subject on the London and South Western Railway where coal-burning engines had been worked for a long time, for the purpose of ascertaining the real lifetime of the tubes under the two circumstances. The result was found to be that in 26 coke-burning engines the average duration of a set of brass tubes was 94,518 miles, varying from 65,000 to 127,000 miles, according to their quality and the description of coke used. But in several engines running with half coal and half coke the tubes had run 154,955 miles, and were still in good working condition; and in one of these engines the tubes after 137,676 miles' work were not half worn out, and were reduced in thickness only from No. 13 to No. 16 wire gauge, or from ·095 to ·065 inch. From the results of this investigation he was satisfied that the ordinary wear of the tubes was caused mainly by the cutting and abrading action of the hard particles of coke drawn rapidly through the tubes, and was not entirely a chemical action as had been at first supposed; and consequently the comparative softness of the particles of coal greatly reduced this cause of wear. This was illustrated by the wear that ordinarily took place in the fireboxes of coke engines, in which the roof and upper portion were reduced only $\frac{1}{32}$ inch in thickness, whilst under the fire door and at the lower part of the sides where exposed to the continued wear of the hard pieces of coke the thickness became reduced $\frac{1}{8}$ inch in the same time. He was satisfied that the durability both of tubes and fireboxes would prove much greater with coal alone; and that there was no ground to fear more chemical action from sulphur with coal than with coke.

Mr. J. E. Clift enquired what proportion of sulphur there was in the Welsh steam coal, as it was not stated in the analysis given in the paper.

Mr. Tomlinson replied that the quantity of sulphur was very small, and was included in the 2·13 per cent. of nitrogen, &c.; in the Four Feet Vein the proportion of sulphur seldom exceeded from 1 to $1\frac{1}{2}$ per cent., and was never more than 2 per cent.

Mr. W. G. Craig said he was completely satisfied, from the results of working of the engines, that the tubes had a much greater durability

with coal than with coke; and the same result had been obtained on several other railways where the trial had been made: when using two thirds coal and one third coke the tubes were found to be still in good working order after running 150,000 miles, but with coke they were worn out in about 100,000 miles. For the purpose of burning coal he had used a firegrate constructed with each alternate bar raised 1 inch above the others, making a kind of hollow fire, leaving spaces for air to enter under the fuel; the bars were not found so liable to burn in that arrangement as with a level grate, being protected by a greater supply of air on their top surface; a set of bars now lasted several weeks with coal, instead of only one week as before when they were all level. The saving in cost of fuel would vary on different railways according to the relative price of coal and coke, and a saving of 30 per cent. in total cost of fuel had been effected by the use of coal upon the Manchester Sheffield and Lincolnshire Railway. The quantity of fuel consumed per mile was less with coal than coke with good drivers, but it required the men to be accustomed to the working of the fuel in order to obtain the full results from coal: the fire had to be kept very thin, and in passenger engines the bars could frequently be just seen in the centre of the fire; there was then always a bright flame from such a fire, effecting the combustion of the smoke, and keeping up the steam better than with the lower temperature of a coke fire; while with coke the fire had to be heaped up almost to the door, and much of the fuel was lost by being carried away unconsumed through the tubes.

Mr. J. Fenton observed that the low evaporative duty obtained from the Newcastle coal, when burnt without consuming the smoke, showed the great importance of ensuring a sufficient supply of air for bituminous coal, and a considerably larger quantity than was required for a coke fire.

Mr. W. Smith remarked that he had seen a construction of cast iron channelled firebars by Mr. Gray, in an application of which every alternate bar was raised about $1\frac{1}{2}$ inch above the rest; sloping notches or channels were made across the top edges of the bars, to afford an increased area for supply of air; several sets he believed were at work in London, burning coal, and they appeared to answer satisfac-

torily, giving an increased supply of air and lasting longer than the ordinary bars from the greater cooling effect of the air.

Mr. Tomlinson said he had tried a set of Mr. Gray's firebars for a stationary engine grate under a large Cornish boiler, but had not found there was much advantage over a set of thin cast iron bars which he had tried in a companion boiler of the same description; the latter bars were $3\frac{1}{4}$ inches deep by $\frac{3}{4}$ inch thick at top and $\frac{1}{2}$ inch at bottom, with $\frac{3}{4}$ inch spaces. In both boilers the firedoors were perforated in the same manner as the locomotive firedoor, and provided with sliding shutters to close the air holes; there was also a damper below the fire to shut up all close when the incline was not being worked. He thought that in practice the channels across the bars were more frequently filled with dust than clear, and hence the absence of any good effect resulting from them. The bars that he used for locomotives were of wrought iron, $4\frac{1}{2}$ inches deep by $\frac{7}{8}$ inch thick at top and $\frac{5}{16}$ inch at bottom, with $\frac{5}{8}$ inch spaces when new. In some engines the same set had lasted five months when burning about 45 lbs. of coal per mile and running about 500 miles per week; the average duration was about three months, which was gradually increasing.

Mr. R. Laybourn observed that an important consideration in the matter was the great variation in the quality of coal obtained in different districts, so that a special plan had to be arranged on each different railway to suit the coal to be used there. The Monmouthshire Railways afforded a remarkable illustration of this, as they comprised five different lines diverging from one locality, and running up five separate valleys which had each a different quality of coal, the quality changing successively from the most eastern valley where it was highly bituminous, to the most western where it was semi-anthracite. The Aberdare and Swansea coals were still more anthracite and were situated further westward. He had made trial of a plan of firegrate by Mr. Jeffreys, of the Shrewsbury and Hereford Railway, in which the bars were laid flatways, on the side instead of the edge, with air spaces between and partly overlapping one another, forming a gradually sloping surface from each side of the firebox down towards the centre; this arrangement proved successful in admitting a larger supply of air, and he found it effective in burning the bituminous coal.

The CHAIRMAN observed that this was similar to Mr. Crampton's firegrate that was used on the French railways, except that in the latter the bars were laid transversely instead of longitudinally in the firebox, forming a surface sloping down from the firedoor towards the tube plate.

Mr. E. A. COWPER observed that in Mr. Gray's plan of firebars that had been referred to, the general arrangement he believed was to have $\frac{1}{2}$ inch bars and $\frac{1}{2}$ inch air spaces, giving 50 per cent. area of opening in plan for the admission of air; but the effective area was increased to 60 or 70 per cent. by cutting sloping notches in the top edges of the bars, so that portions of the top surface of the bars were cut away; he did not know what were the results of their working, but thought the use of very thin bars fully answered the purpose required; he usually employed bars only $\frac{1}{2}$ inch thick at top and $\frac{1}{4}$ inch at bottom, with $\frac{5}{8}$ inch spaces.

Mr. TOMLINSON said that a set of Mr. Gray's firebars had been tried for some time in the "Iron Duke" locomotive engine on the Great Western Railway; but he did not think any plan of stepped grate would be suitable for burning the Welsh coal, for he found that if any one of the ordinary bars were accidentally left standing up above the others, from the notch in the firebar-frame not being cleaned out, it was sure to get burned more than the rest.

Mr. E. A. COWPER had heard that a plan had recently been tried in some locomotives on the Great Western Railway, for tipping up the entire firegrate upon a centre bearing, so as to allow of laying the fresh fuel on the bars and then covering it over with the red fire when the grate was tipped back again sharply.

Mr. R. LAYBOURN believed that was Mr. Jeffreys' plan, and was intended as a mode of making cast iron bars suitable for locomotive firegrates: this was effected by never disturbing the cast iron bars on their bed, and they were never removed until worn out; but when the fire had to be dropped the whole frame was tipped over on a centre bearing, allowing the fuel to drop out. This plan gave great economy in the cost of maintenance of firebars, as cast iron was used instead of wrought iron bars; and the bars were preserved from injury by avoiding the handling of them whilst hot, which was liable to bend or break them.

Mr. J. Fernie said an arrangement of ridged firebars had been tried for a stationary engine boiler at Derby, on Mr. Chanter's plan, in which the top of the bars was ridged or serrated, and every alternate bar was moved longitudinally about 1 or $1\frac{1}{2}$ inch backwards and forwards, the intermediate bars remaining stationary; the alternate bars were moved by a transverse shaft provided with a lever which was moved occasionally by the stoker. These had been in use about two years, and were found to answer the purpose satisfactorily; the ridges on the bars served to keep the fire gently stirred, preventing clinkers from adhering to the bars.

Mr. W. G. Craig observed that for burning coal it was requisite to have the bars rather close together and very thin, considerably more so than with coke; and the object he had had in view in using a grate with the alternate bars raised above the others was to admit more air under the fuel, making a kind of hollow fire, to prevent the bars from burning. The firebars he used were $\frac{7}{8}$ inch thick at top and $\frac{1}{2}$ inch at bottom, with $\frac{3}{4}$ to $\frac{7}{8}$ inch air spaces, and when placed alternately raised they could be brought still closer.

Mr. J. E. Clift enquired whether a pan of water had been tried under the firegrate, to prevent the bars being burnt; that plan was frequently used in stationary engines with good results, and by this means he had had firebars in constant use for two years with intense coal fires under gas retorts, without the bars burning away. There was constantly a supply of water under the firegrate, and the steam rising from it served to keep the bars continually protected and cool.

Mr. Tomlinson said he had tried a jet of water from the boiler kept continually running under the firegrate of a locomotive during the whole trip, but it did not serve to protect the bars from burning; he had not tried a pan of water, but with the jet there was so much water constantly supplied as to keep the ashpan full of steam, and he thought the effect would be the same as in the use of a pan of water.

Mr. T. T. Chellingworth remarked that a water pan was generally used under the firegrate in agricultural engines, with good results in preserving the bars.

Mr. C. W. Siemens observed that the efficiency of the water below the firegrate would depend a good deal upon the quantity of ashes

falling from the fire; if the ashes fell easily they would keep up a supply of steam from the ashpan and preserve the bars from injury; but if much clinker were formed on the firegrate, the water pan would not answer, as there would not be steam enough to keep the bars cool.

Mr. J. FERNIE thought the paper that had been read was very serviceable as the introduction of a particularly important subject, and he hoped it would lead to a series of papers on coal-burning; for it was most essential to the railway companies to be able to use coal, and nearly all of them were now entering into the matter, as to the saving both in cost of fuel and in expense of renewal of tubes and fireboxes. On most railways experiments were now being made on the subject, and many different contrivances with firebrick and other plans were being tried; on the Midland Railway they were now engaged in experiments for the purpose, and he would be happy to give the results at a future time. He thought that something very simple was wanted, and did not see why the object should not be satisfactorily accomplished in time. The object of burning coal without smoke in locomotive engines had been well effected by means of complicated apparatus; but they were obliged to consider the large stock of coke-burning engines at present on the railways, and the consequent impracticability of changing them for coal-burning, unless this could be done at a moderate cost and slight trouble of alteration.

As to the effect of sulphur in coal upon locomotive tubes, it might be noticed that in the early engines of the Liverpool and Manchester Railway the tubes were of copper brazed with brass, and a chemical action was found to take place upon the copper from the sulphur in the fuel; but with the present brass tubes the case was quite different, and there could be no doubt that the wear was entirely due to the mechanical action of the hard particles of coke cutting away the metal.

The CHAIRMAN observed that the discussion had proved highly interesting and valuable, and he hoped it would be continued by another paper on the subject at a future meeting.

He moved a vote of thanks to Mr. Tomlinson for his paper, which was passed.

The following Paper, by Mr. Thomas T. Chellingworth, of Westbromwich, was then read:—

DESCRIPTION OF A DIRECT-ACTING EXPANSIVE STEAM ENGINE.

The very general use of high-pressure non-condensing steam engines makes the economy of their working and construction a matter of considerable importance. There are many cases in which circumstances will not admit of the use of a condenser, such as the absence of a good supply of water without deep wells and expensive apparatus for lifting; or where the work to be done or the capital available will not admit of the expense of a condensing engine. In any of these cases it becomes a most important consideration that economy in the first outlay, which is a frequent reason for the use of a non-condensing engine, should be combined with economy in the working also. The economy obtained with a single slide valve by giving an additional lap and cutting off the steam at an earlier part of the stroke can be carried only to a moderate extent, and the use of a separate cut-off valve is found necessary to obtain the full advantages of expansion.

With the view of obtaining simplicity and economy of construction, the writer has endeavoured in the engine described in the present paper, with a single cylinder and a simple slide valve and without any additional valve gearing, to cut off the steam at an early portion of the stroke after having been admitted at a high pressure, and to expand it very nearly down to the atmospheric pressure. The steam is first admitted to the top of the piston, and after having made about two thirds or three fourths of the down stroke it is cut off and expanded to the bottom of the stroke; the same steam is then admitted to the under side of the piston and expands through the whole of the return stroke; being in fact used in the same manner as if it were cut off at about one third of the single stroke of a cylinder double the length. In order to obtain this result it is necessary to have a piston with two different areas, the steam being first admitted on to the smaller area and then expanded on to the larger one.

The construction of the engine is shown in Figs. 1, 2, and 3, Plates 72 and 73. Fig. 1, Plate 72, shows a front elevation of the engine, and Fig. 2 a longitudinal section; Fig. 3, Plate 73, is a vertical section of the cylinder to a larger scale. The cylinder A is bolted to the base-plate and also to the standard B by snugs at the back. The piston C is cast in one piece and bored out to receive the end of the trunk D, being secured to it by the bolt E which also forms the eye for attaching the connection rod F. The piston is dished and fits into the cylinder cover, leaving only a small space between, the stuffing box projecting inwards; this shortens the height of the engine while it admits of the piston being lightened. The steam ports G and H are placed next to each other, and the exhaust port I underneath instead of between them as in the ordinary construction; the valve K is an ordinary D slide worked by an eccentric and rod; Figs. 4 and 5 show the extreme positions of the slide valve, Fig. 3 showing the position when admitting steam at the commencement of the down stroke. In starting, a difficulty would be caused by a partial vacuum being formed by condensation of the steam before the lower part of the cylinder gets heated; this is obviated by the starting valve L, consisting of a small conical plug which is drawn back by a screw, and opens from the steam chest into the top port G, by means of which the engine is easily started at any point of the stroke.

In this engine the steam is first admitted through the top port G, as in Fig. 3, and acts on the annular space round the trunk D, being cut off and expanding in proportion to the lap of the valve: then in the return stroke the two steam ports G and H are thrown into communication with each other by the inside of the same slide valve, as in Fig. 5, and the same pressure acts on both sides of the piston, the return stroke being made by the unbalanced pressure of the expanding steam acting upon the area of the trunk; and during this up-stroke there is no back pressure from exhaust. Fig. 6, Plate 73, shows the indicator diagram taken from this engine, the full line being the diagram from the upper side of the piston and the dotted line from the under side, the bottom line of the one and the top line of the other being necessarily identical; the speed of the engine was 60 revolutions per minute.

The engine shown in the drawings is working at the writer's works at Westbromwich, and an engine of similar construction at Mr. Dowler's works in Birmingham; in the latter engine the connecting rod, instead of working direct on to the crank, is connected to the end of a beam, the present cylinder being in the place of one of the ordinary construction which has been removed.

The CHAIRMAN asked how long the engine had been working, and what pressure it was worked at.

Mr. CHELLINGWORTH replied that the engine was about 4 horse power and worked with 40 lbs. steam in the boiler; and it had been 8 months at work. He showed the piston and trunk taken out of the engine; the piston had been working at present without packing, with merely a groove turned round the centre to receive a packing ring, the groove being supplied with oil by two small holes from the centre of the piston; the piston was found to work well and steam tight, having a great length to serve as a guide.

Mr. B. FOTHERGILL enquired what was the consumption of fuel.

Mr. CHELLINGWORTH replied that the consumption had been 21 cwt. of engine slack during a 6 days' trial of 10 hours per day.

Mr. J. E. CLIFT said he had seen the engine at work and had seen the indicator diagrams taken; it worked very satisfactorily, the up and down strokes being nearly uniform, and it ran steadily at a high speed; it was simply a means of carrying the principle of expansion much further in small engines than was usual, with a simple, compact, and very economical construction; and he had no doubt it would be found an efficient engine.

Mr. W. SMITH observed that the general arrangement of the engine appeared to be the same as had been adopted in several previous plans of trunk engines, and he did not see any novelty or special advantage in the one now shown; he thought the cylinder should have a steam jacket if it was intended to be economical in working.

Mr. Chellingworth said the only object had been to get a simple and convenient expansion engine, giving a considerable degree of expansion with an ordinary single slide valve, cheap in manufacture and economical in working, and suitable for the cases of ordinary small engines, which were generally very imperfect in economy of steam. A steam jacket had not been used in the present engines, as economy of construction was specially aimed at; but he intended to add a steam jacket where practicable, to prevent the drop of pressure shown in the indicator diagram on letting the steam into the bottom of the cylinder.

Mr. I. Smith remarked that with a flat cut-off slide working on the back of the valve the steam might be readily cut off at any part of the stroke in an ordinary cylinder by the addition of a simple expansion gear. He had lately seen an engine working at Bolton with a good form of expansion gear of this description by Mr. Schiele, in which the steam was cut off either very early or later in the stroke as the work to be done required more or less steam, by means of the ordinary governor being connected to the expansion gear, which served to regulate the engine without the intervention of a throttle valve: he had seen the indicator diagrams obtained from the engine, which showed a very high degree of expansion.

Mr. J. Inshaw said he remembered an engine many years ago, of a similar construction to that described in the paper, in which the trunk was two thirds the area of the cylinder, and the steam was superheated by means of a firegrate below the cylinder.

The Chairman referred to the intended meeting at Leeds next summer, and hoped it would prove as interesting as the recent meeting at Newcastle. He observed that the accession of new members that had taken place in each district where the special provincial meetings had been held was highly gratifying and was an additional proof of the success and importance of these meetings.

Mr. J. Fernie remarked that, in order to render the Institution as valuable as possible, the Library ought to be extended and supported by the members ; they had already a number of books as a commencement, including a handsome donation of useful works from the Chairman, which he hoped would be added to by the members.

The Chairman observed that he had long felt the necessity for a library ; and suggested that if any of the members had duplicate engineering books in their possession they should give one copy to the library of the Institution, by which means a collection would be obtained forming a good starting point, which might be extended in future as means allowed so as to form a really valuable library of practical and mechanical works.

The Meeting then terminated.

After the meeting some specimens of boiler plates were exhibited by Mr. John Fernie, of Derby, for an improved construction of steam boilers, without angle iron and with increased strength at the rivet holes, by making the plates with the edges thickened, to admit of flanging over and punching without any reduction of the strength at the joint below that of the body of the plate ; specimens were also shown of worn and fractured plates of the ordinary make, taken from locomotive boilers.

Fig. 1. *Elevation.*

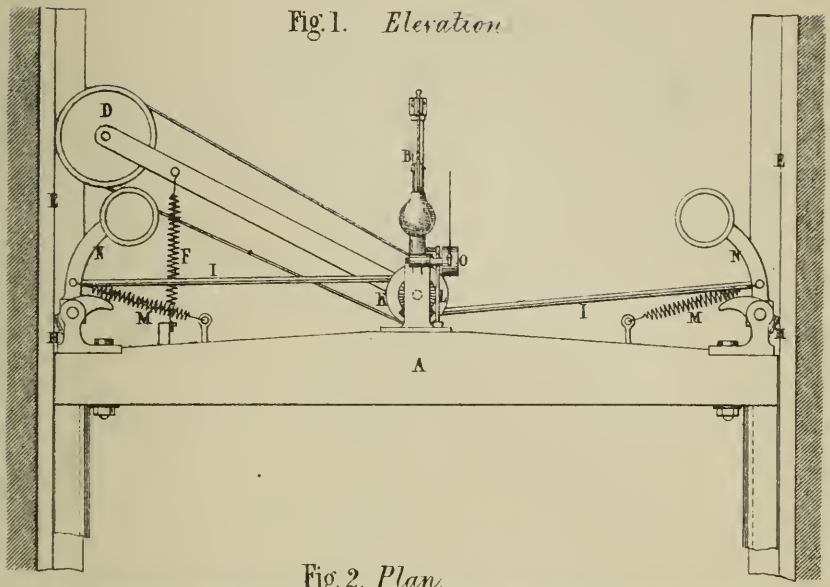
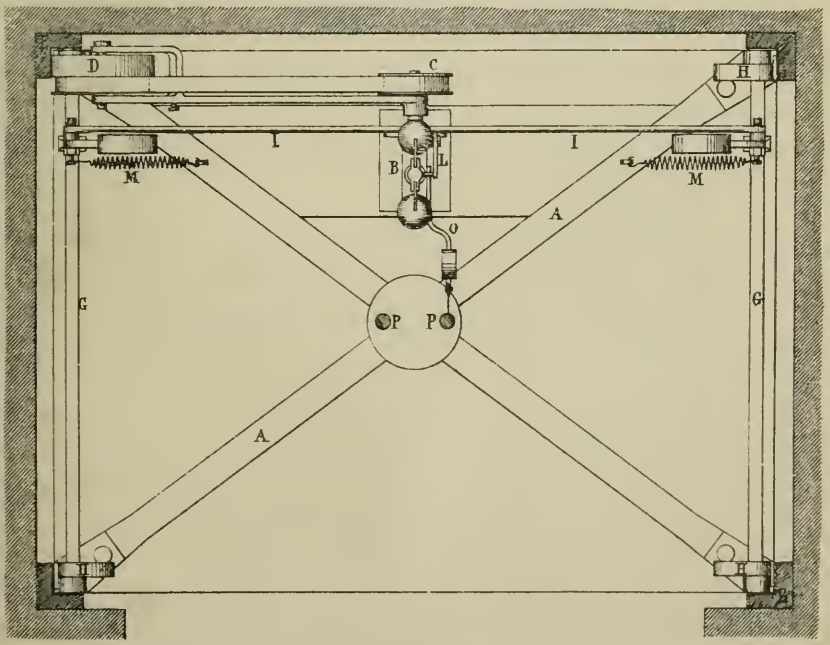


Fig. 2. *Plan.*



Scale 1/20th.

Ins. 12 9 6 3 0 1 2 3 4 5 Feet

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SAFETY HOIST GOVERNOR.

Fig. 3.
Elevation of Governor.

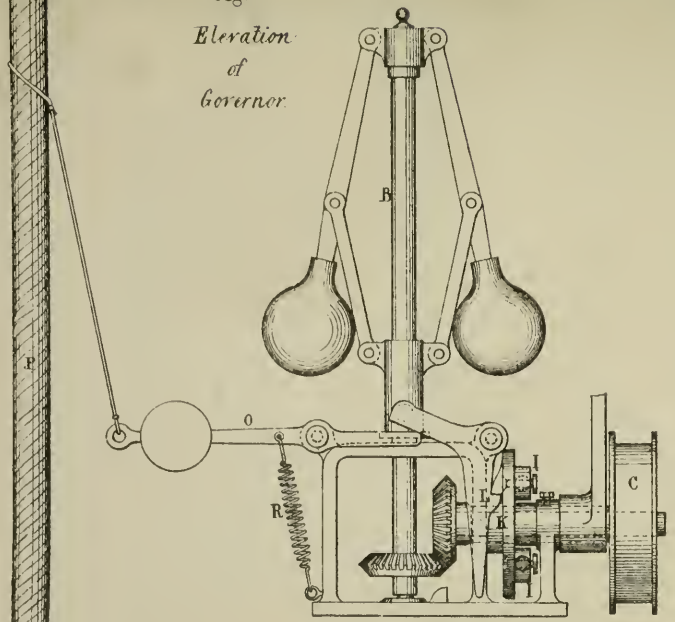

Fig. 4.
Elevation of Break Cam.

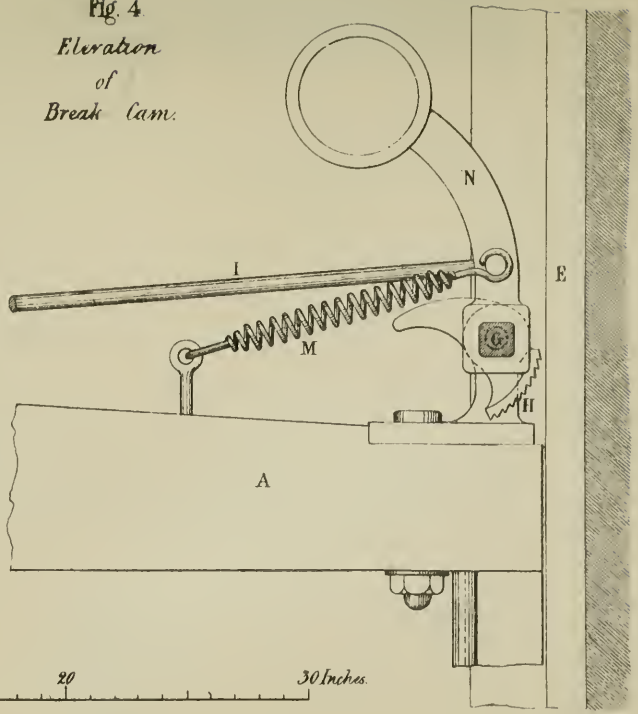

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Plate 70

Fig. 1. *Longitudinal Section of Firebox.*

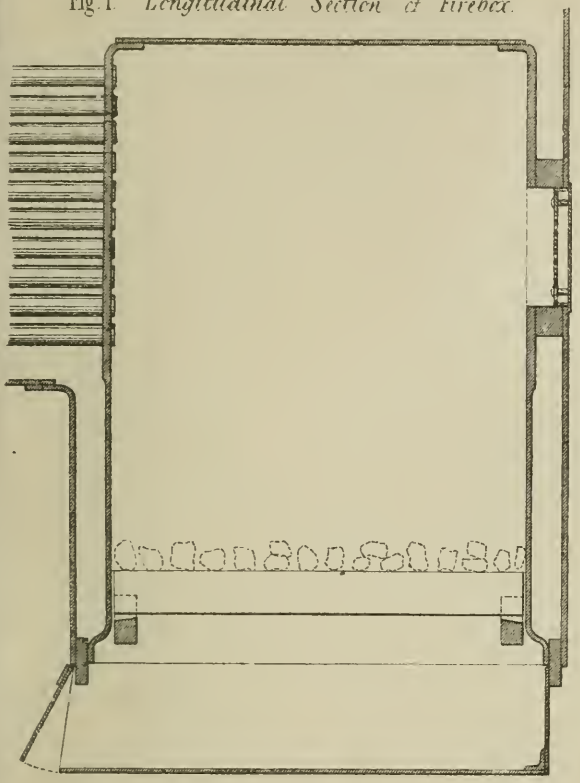

Fig. 4

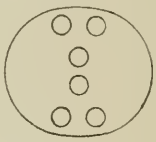

Fig. 5.

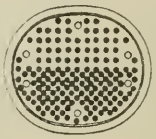

Fig. 2. *Transverse Section*

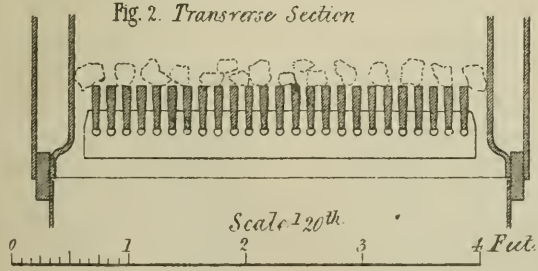

Fig. 3.
Section of Firebars enlarged.

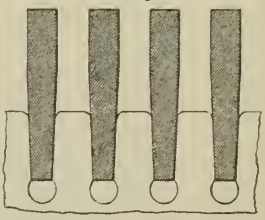

Fig. 6. *Section of Taff Vale Railway.*

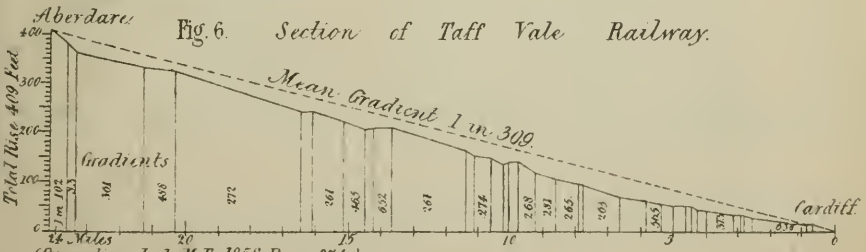

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Fig. 1.
Front Elevation

Fig. 2.
Longitudinal Section

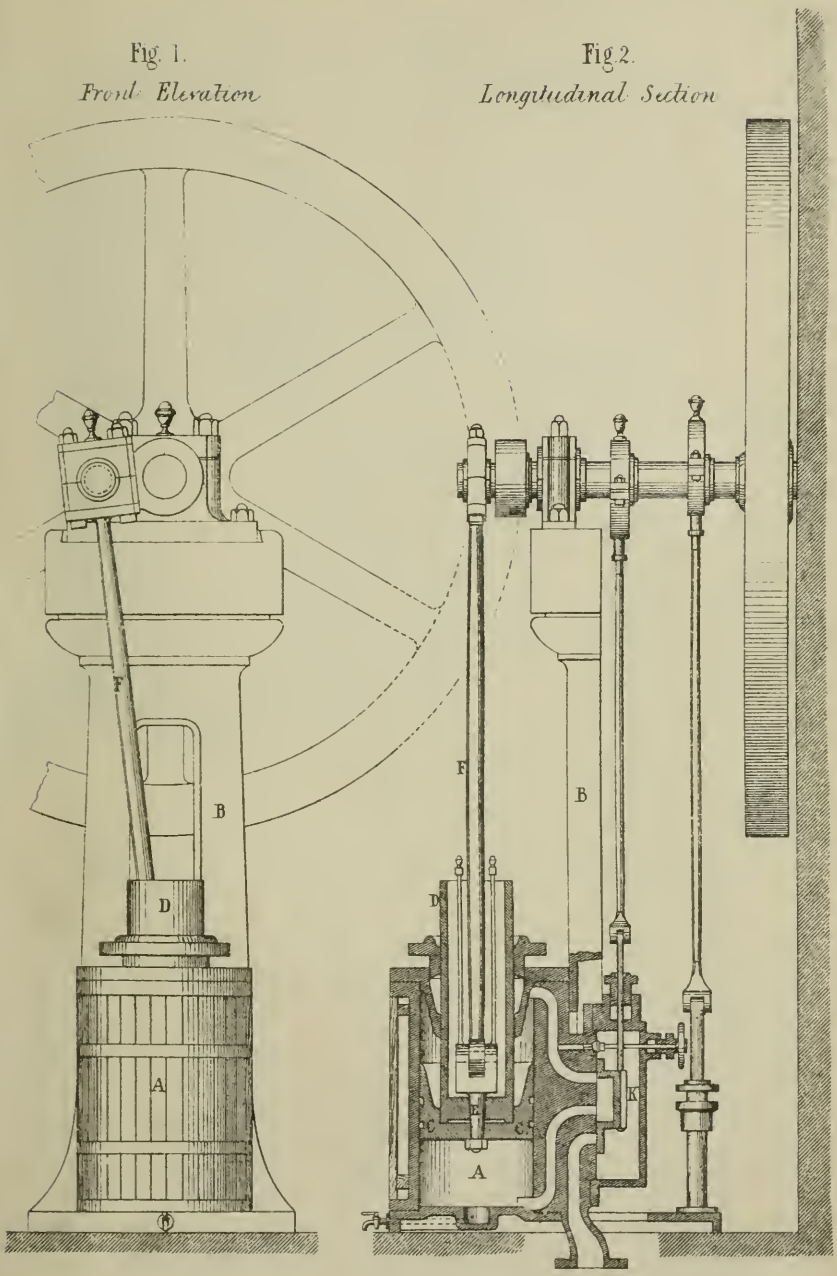

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Fig 3
Section of Cylinder and Valve

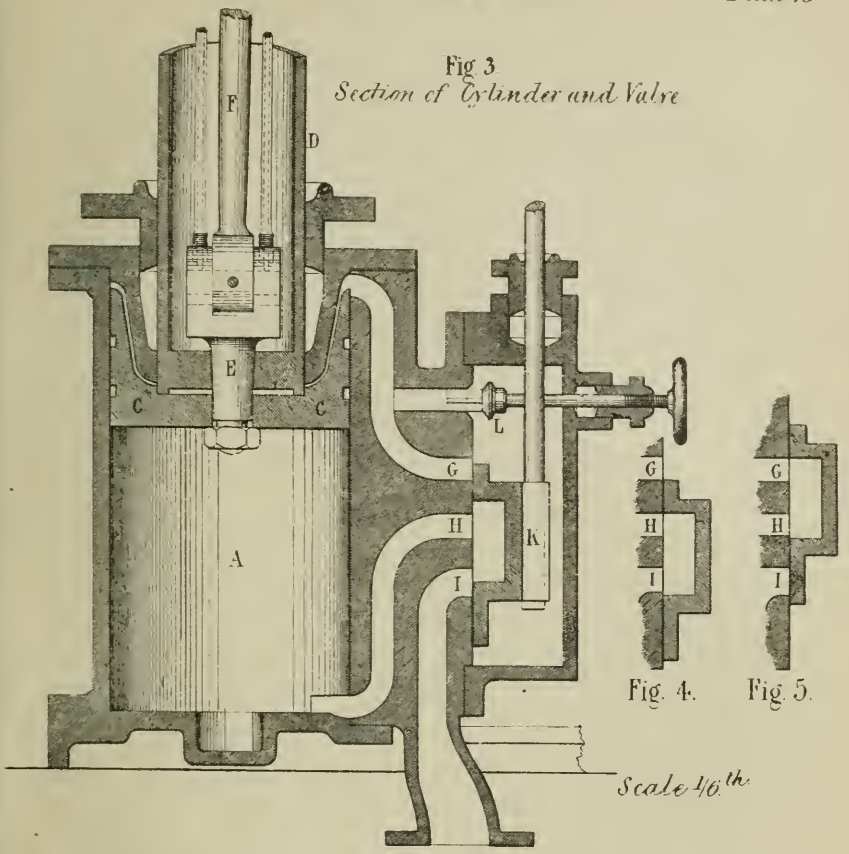
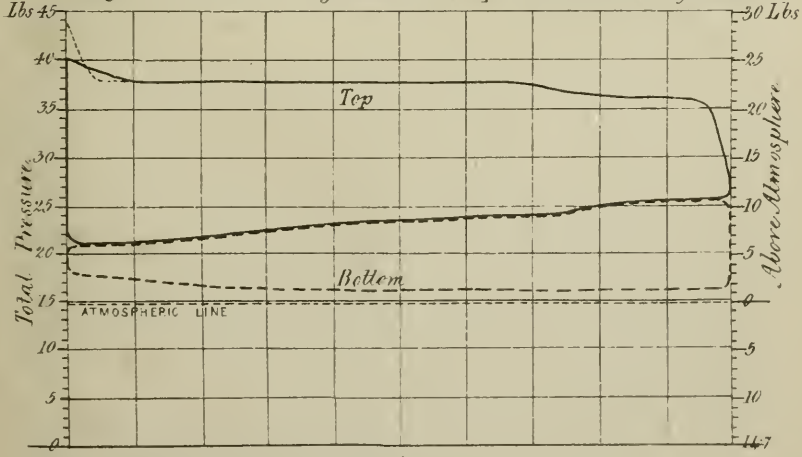


Fig. 4.

Fig. 5.

Fig.6. *Indicator Diagrams from Top and Bottom of Cylinder*



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